1917
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Bennitt

Design of a Modern Steel Mill Building

DESIGN OF A MODERN STEEL MILL BUILDING

BY

RALPH ANDERSON BENNITT

B. S., UNIVERSITY OF ILLINOIS, 1913

THESIS

SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE

DEGREE OF
CIVIL ENGINEER

IN

THE GRADUATE SCHOOL

OF THE

UNIVERSITY OF ILLINOIS

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THE GRADUATE SCHOOL

May 1, 1917 191

I HEREBY RECOMMEND THAT THE THESIS PREPARED BY

RALPH ANDERSON BENNITT

ENTITLED DESIGN OF A MODERN STEEL MILL BUILDING

BE ACCEPTED AS FULFILLING THIS PART ON THE REQUIREMENTS FOR THE

PROFESSIONAL DEGREE OF Civil Engineer

F.W. Newell

Head of Department of Civil Engineering

Recommendation concurred in:

L. P. Harman
A N Talbot
} Committee

376705

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FOREWORD.

The art of designing and constructing factory buildings of the type commonly known as "Mill Buildings" is a distinct branch of engineering work. The author believes that a great deal of capital is expended uselessly through the making of individual designs, because of the time spent on the design, the letting of contracts, the fabrication of the various parts; because of money spent during this period due to advancing costs; and because of lack of co-operation between the Owner, the Engineer, and the Contractor. In order to obviate these difficulties a great many organizations have been formed in this country, known as "Engineers and Contractors" who do their work on a cost plus commission basis. They have standardized their designs of the various parts of the buildings, the details, their specifications, their basic costs, their accounting, and their methods of construction, and are thus able to eliminate a great waste of time and materials.

But a few companies have taken a bold step still further in advance, and by having ready-fabricated the structural steel and timber for certain buildings, standard steel sash, standard doors, etc., bought at a favorable time and in large quantities, they are able to effect a great saving in time and money to the Owner; for they are able to deliver over the building for operation by the time which would be consumed up to the point of letting the contract, if done in the ordinary way.

Careful analysis of large industrial plants has proved, conclusively, that no matter how highly specialized certain portions of these plants may be, there is a striking similarity in 30% to 40%

of the floor space. Yet manufacturers of standard products, knowing full well that in their own case standardization enables them to manufacture their product in quick time and at low cost, treat every building they construct as an individual project.

These facts were recognized by the Hooker Electrochemical Company, and while the design of the building and of the equipment called for a great deal of specialization, they were made to conform as far as possible with Austin Standards; and thus a great deal of time and expense was saved in the field and the office, because of the availability of the materials, and the familiarity of the organization with them.

The general scheme of manufacture of the product determined the type, size and shape of the structure. Structural steel was selected for the skeleton framing, primarily because of the speed with which it could be erected; and secondly, because of its flexibility in regard to changes in location of equipment, and future expansion. Concrete was used to a considerable extent because of its adaptability of shape for equipment, and for its caustic-resisting properties. No wood framing was used, since the action of the caustic soda would make its use short-lived. This chemical action was given due consideration in connection with the use of structural steel, but it was decided that by careful maintenance, the life of the structure would be prolonged beyond the period required for the return of interest and the additional investment.

In making the detailed designs, current practice was followed, and the application of accepted fundamental theories is shown by typical designs of the various parts. It is believed that engineers can derive considerable benefit from the methods of attack

used by others, and it is hoped that this thesis, while not analyzing basic principles of design, will still bring out their application to practical problems.

The author was a part of the staff of The Austin Company's designing engineers, and had charge of the design of all the concrete work, as well as many of the mechanical features, sewerage, track, and building plans, and their details.

THE CONSTRUCTION OF A UNIQUE FACTORY IN WAR-TIME.

I. INTRODUCTION.

The Evaporation House was one of a number of buildings proposed to be constructed by the Hooker Electrochemical Company for the manufacture of caustic soda and its by-products. By utilizing a portion of the great power of Niagara in the recently discovered process of manufacturing caustic soda electrochemically, this company was able to produce large quantities at a low cost. The demand for their product has grown year by year, for the sodium salts, caustic soda, soda ash, and chlorine, which they transform from common salt, are of vital importance in the industrial and civic world. They are used as disinfectants; for bleaching; and in the manufacture of soap, glass, paper, and picric acid; and, therefore, have a field of usefulness in laundries, in textile mills, for purification of city water, for hospital use, and for many other purposes.

Chemical works manufacturing these products exist on a large scale in most civilized countries. The European War brought about an abnormal condition of supply and demand, and the effect was soon felt in this country. Shipments from Europe practically ceased, as these chemicals are of great importance in modern warfare. Japan had supplied most of the needs of Russia and China, while the United States, England and Germany were furnishing these products to South America. For a short time after the war began, our manufacturers were able to continue supplying the trade in the ordinary way, but the large export business soon made heavy inroads

upon their holdings.

In view of the urgent necessities of a large group of American and foreign industries dependent upon the supply of caustic soda, it seemed evident to the Hooker Electrochemical Company that the time was ripe for expanding their plant, for they had an unlimited market, with prices soaring.

But they were obliged to face war-time conditions, and the design and construction of a plant such as theirs involved the overcoming of stupendous difficulties. It meant planning an immense amount of equipment down to the minutest details; it meant planning and constructing not only a building for housing the equipment, but also a maze of steel and concrete which was necessary in the operation; it meant getting materials from manufacturers who were already working at their maximum capacity; and shipping by railroads choked with traffic in an era of industrial prosperity such as the country had never before experienced.

Several other great difficulties loomed up big in launching this immense enterprise. The problem of expansion presented itself, for while proposing to construct a plant that would meet the demands of the present, the company was obliged to study the industrial and political conditions of this and foreign countries; forecast the needs of the future and plan the operating units to meet them. Another practical problem was the gathering of forces of brain-power and body-power, and molding them into a loyal, enthusiastic organization which would be capable of carrying through such an immense task in the most efficient way.

But the most important problem of all was to have the

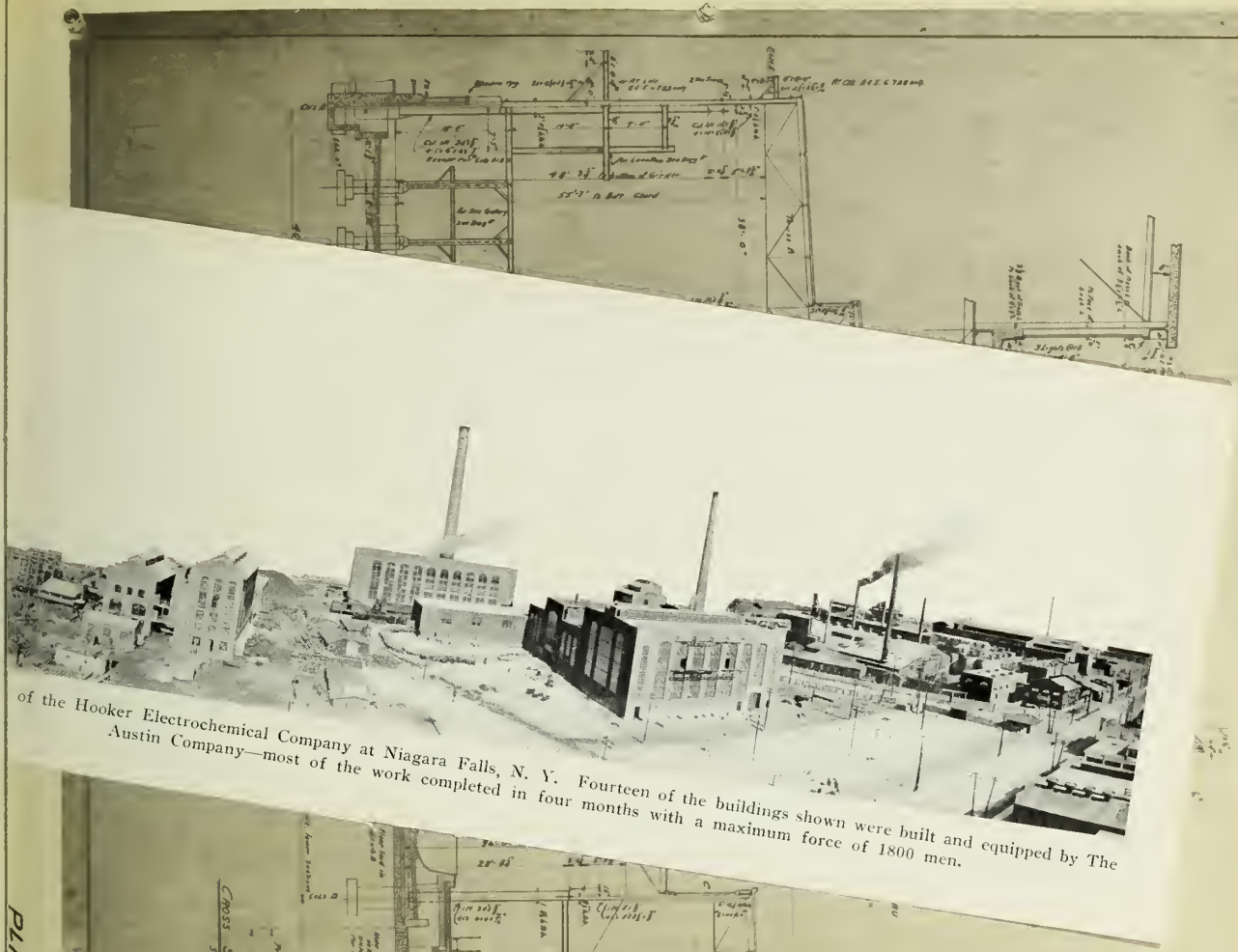
plant operating at the earliest possible date, and in order to do this they must needs instill into the concentrated forces the one big idea of speed, that this idea might influence the whole construction as a mighty, driving force through every operation.

It is the purpose of this thesis to give the design of the various parts of this complex factory, and to show how this design was affected by the equipment; by the plans for future extension; by the high speed in construction; and by the extraordinary economic conditions brought about by the war.

II. THE DESIGN.

The Austin Company, Engineers and Contractors, of Cleveland, were selected as being well able to carry through an enterprise of this kind, because of their long experience in this class of work. Their part was to co-operate with the engineers of the Hooker Electrochemical Company and provide the building, install the equipment, design and construct such other features as were required for the operation of the plant. The engineers for the Hooker Electrochemical Company laid out the scheme of operation, no methods being overlooked which would give the easiest and most logical handling of the manufacture of the caustic soda. In this way the two companies worked together, and were able to put through the design of the building, and the operation of the plant in perfect harmony.

The order of design and construction was closely allied with the route of operation. The underlying principle of manufacture in the Evaporation House was the evaporation of the liquor, piped from the old plant. This liquor was simply a chemically pure salt brine, broken down by electrolysis into free hydrogen, free chlorine, and sodium hydroxide (NaOH) or caustic soda, in a liquid form. The liquor was ordinarily stored in huge tanks high above the floor, and was fed by gravity into evaporator tanks. Here it was partially evaporated by steam, discharged into filtering and cooling tanks; thence conveyed to huge pots over the furnaces. It was heated in the pots to a high temperature, and discharged into small sheet-iron drums setting on trucks. These



of the Hooker Electrochemical Company at Niagara Falls, N. Y. Fourteen of the buildings shown were built and equipped by The Austin Company—most of the work completed in four months with a maximum force of 1800 men.

PLATE I.

and are being constructed, individual work is the larger part of the Austin business.

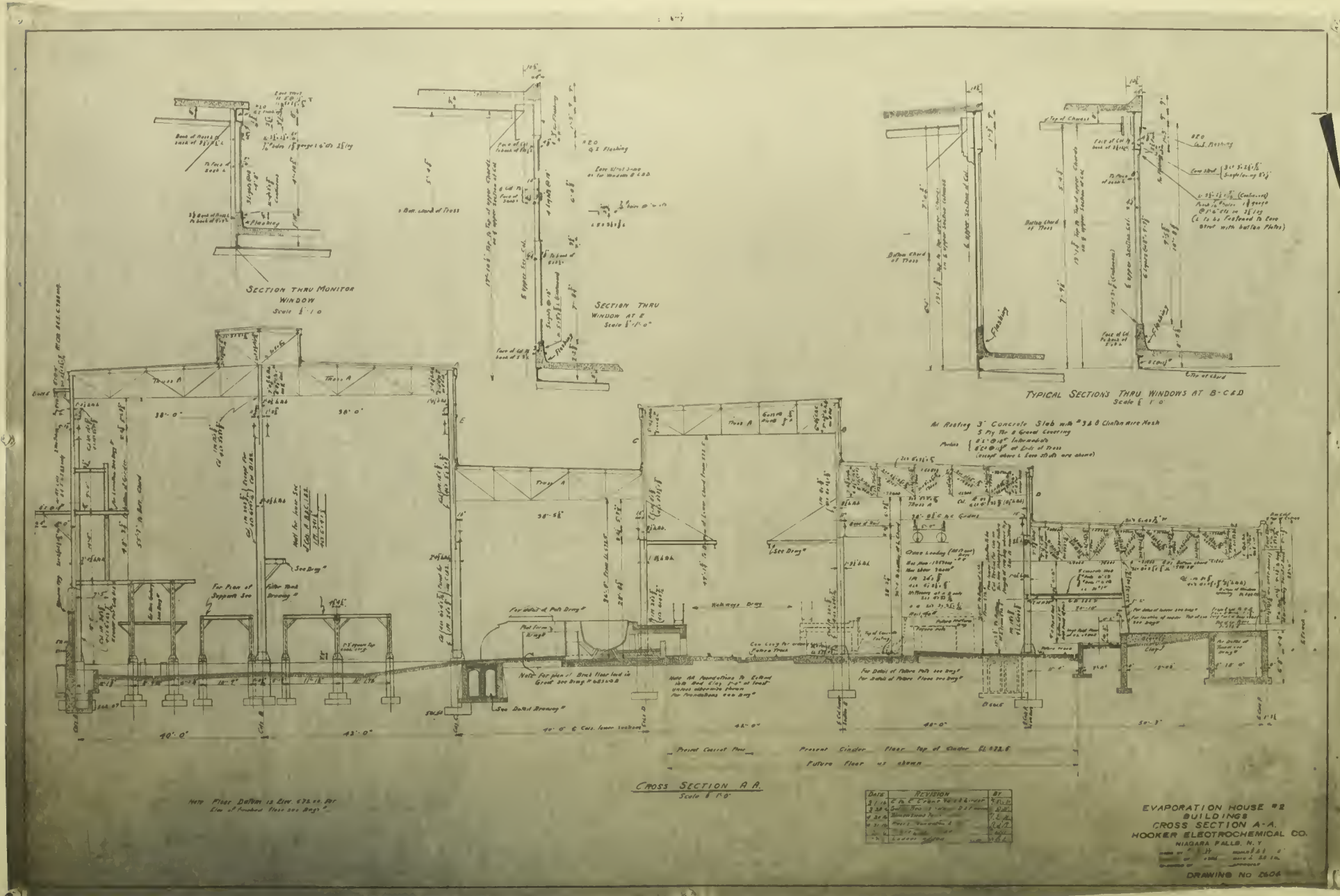
The Austin Company provides an efficient, comprehensive service in engineering, construction and equipment.

Engineering Department—Embraces six geographical centers where instant service is available for customers who desire quick action. Familiar with the lay-out of side-tracks, buildings, power and heating-plants and production-equipment to secure

Equipment Department—Purchases and in stalls heating, lighting, plumbing, power-equipmen and production-machinery as desired. Capably o ganized and manned.

Ninety per cent of the work is do by Austin men—so little sub-letting th the owner is served by practically one ganization, with one responsibility, at profit.

And the owner may exercise his f erence as to the form of contract—l sum, cost plus percentage, cost plus


SECTION THRU MONITOR WINDOW
SECTION THRU WINDOW AT E
TYPICAL SECTIONS THRU WINDOWS AT B-C&D
CROSS SECTION A-A
Present Cinder Floor top of Cinder
Future Floor as shown
EVAPORATION HOUSE #2
BUILDINGS
CROSS SECTION A-A.
HOOKER ELECTROCHEMICAL CO.
NIAGARA FALLS, N.Y.
DRAWING No 2606

trucks were then pushed to the car haul, where they were pulled up to the level of the loading platform. The drums were then sealed, weighed, washed and set aside to cool, awaiting shipment.

Preliminary designs of a building which would meet the conditions for the mechanical equipment were submitted and approved. The design of that part of the building which was to contain the evaporator and filter tanks, the first step in the manufacture, was taken up first. The usual procedure of designing a building was followed, i.e., the roof, crane girders, columns, and column footings were designed in logical order to sustain the loads which were assumed for them. The height of the roof and crane was dictated by the clearance required above the highest part of the equipment. This gave a height to a portion of the building extraordinarily great for this type of building.

The roof was constructed of concrete, on steel purlins and trusses, in order to better resist the caustic fumes. In the design of the roof slab, trusses, and columns and footings, the following assumed loads were used:

Snow Load	25#/ sq. ft.
Slab & fill	50 " "
Roofing	5 " "
Total	80#/ sq. ft.

The Roof Slab.

The stresses used in the roof slab as well as all concrete work throughout the building were:

Tension in steel	16000#/ sq. in.
Compression in concrete	650 " "
Shear in plain concrete	40 " "
Diagonal tension reinforced concrete	120 " "
Bond	80 " "

On account of the slab thickness being but three inches, and the uncertainty of placing the wire mesh reinforcement correctly over the supports, the slab was designed on the basis of WL/8. Example:

$$M = \frac{80 \times 8^2 \times 12}{8} = 7680\#"$$

$$d = \sqrt{\frac{7680}{105 \times 12}} = 2.4" \quad \text{Slab } 3"$$

$$A_s = \frac{7680}{2.4 \times .88 \times 16000} = .22 \text{ sq. in.}$$

Clinton Electrically Welded Wire Mesh of #3 gage wire spaced three inches for the main reinforcing and #8 gage spaced 12" transversely, giving an area of steel of .25 sq. in./ft. of slab width, was used.

The Roof Trusses.

The roof trusses were designed for the vertical loads, only, as given above, no allowance being made for wind, because of the flat slope, one-half inch per foot. As the uncovered steel work is liable to corrosion, on account of the caustic fumes, a minimum thickness of metal of 5/16" was adopted, and in proportioning the members the following stresses were used:

Compression	(16000 - 70 l/r)	x .75
Tension	(16000#/sq. in.)	x .75

For details of connections, the rivets were designed on the basis of 6000#/sq. in. and 12000#/sq. in. for shear and bearing respectively, irrespective as to whether they were shop or field rivets.

The purlins were spaced to carry the load to the truss at the panel points.

Purlin W = (80 x 8 + 20) 15 = 10.0k

Sec.Mod.S = $\frac{10 \times 15 \times 12}{16.0 \times 8}$ = 14.1 In.^{3}

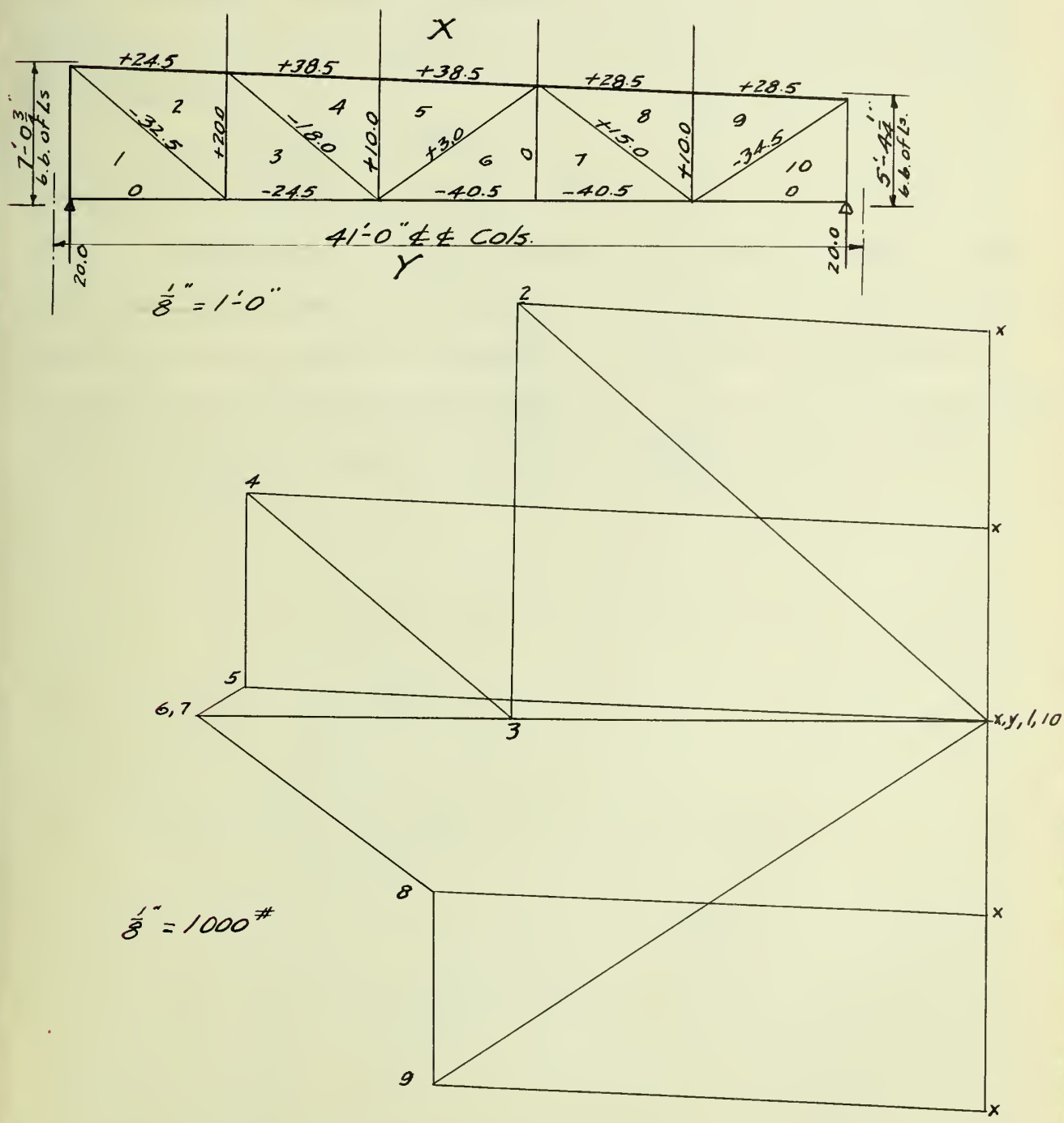
8" I - 18# has S = 14.3 In.^{3}

This purlin section was used throughout the building except between trusses from columns A-B-C, where 9" I's-21# were substituted on account of not having all the 8" I Beams in stock.

The stress diagram for a typical truss is shown in Fig. 1. The trusses were to be shipped assembled so the chord members were made of the same section for their full length.

Fig. 1.

- Truss and Stress Diagrams -



Top chord max. stress = + 38,500# l = 8'-0" or 64".

Section designed was:- 2Ls - 5 x $3\frac{1}{2}$ x 5/16; A = 5.12 sq. in.;

Least r = 1.37" for 5/16" gusset plates.

Actual $f_c = \frac{38500}{5.12} = 7550\#/\text{sq. In.}$ $\frac{l}{r} = \frac{64}{1.37} = 47$

Allowable $f_c = 12700 \times .75 = 9500\#/\text{sq. in.}$

Bottom chord max. stress =-40,500#

Section:- 2Ls - 4 x 3 x 5/16; net A = 4.18 - .54 = 3.64 sq. in.

for 2-7/8" holes.

Actual $f_t = \frac{40500}{3.64} = 11{,}200\#/\text{sq. in.}$

Allowable $f_t = 16000 \times .75 = 12{,}000\#/\text{ sq. in.}$

The web members were designed in a similar manner. The trusses were detailed and fabricated by The Buffalo Structural Steel Company and the sizes and strength of connections were checked by the designing engineers before approval. Connections were designed on the above basis to develop the full strength of the members.

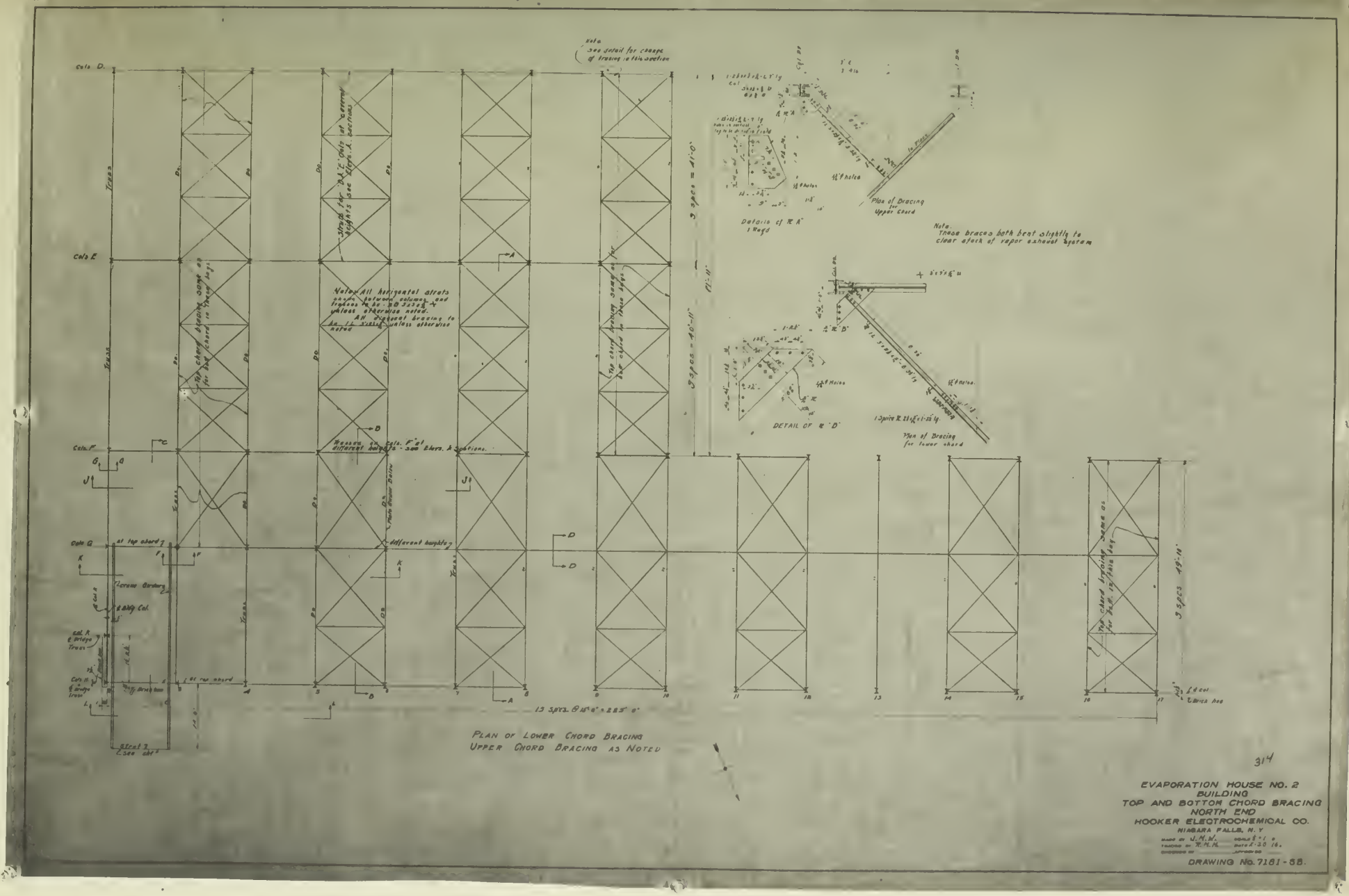
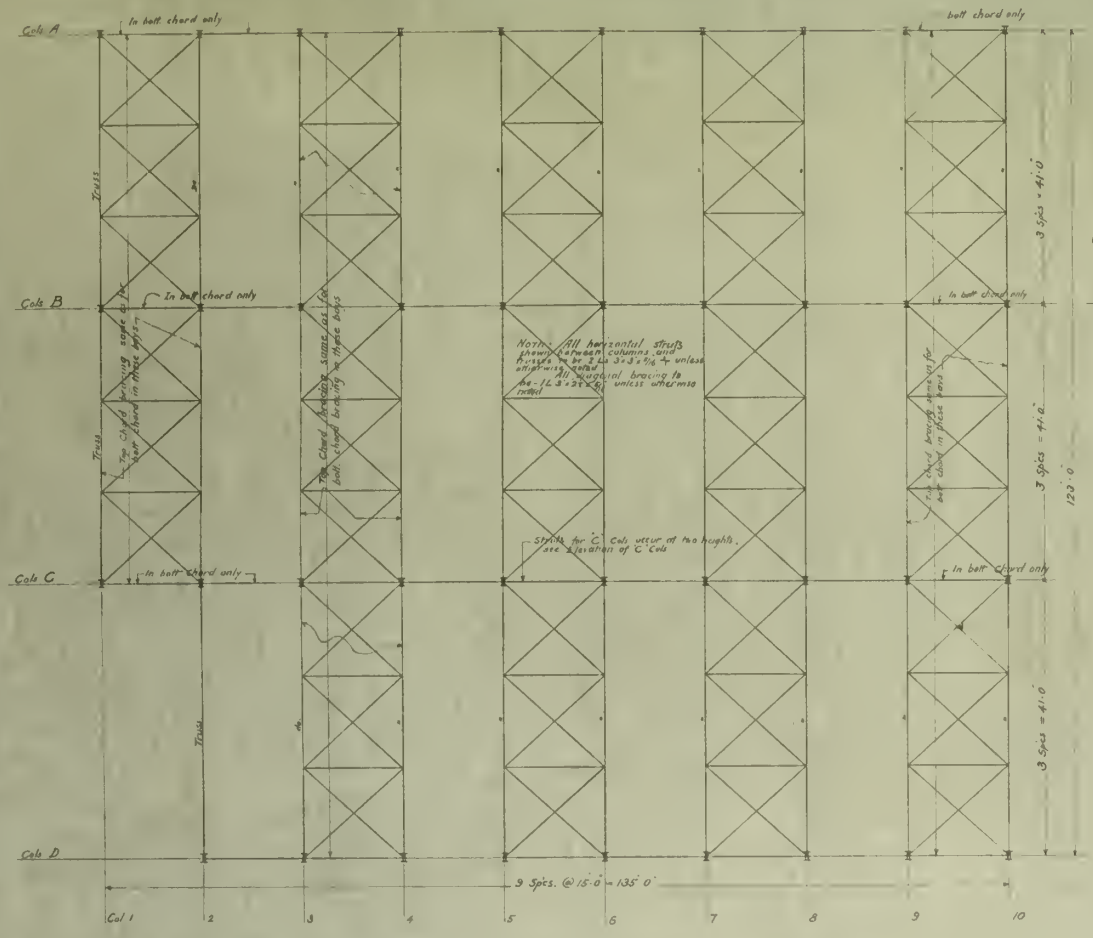
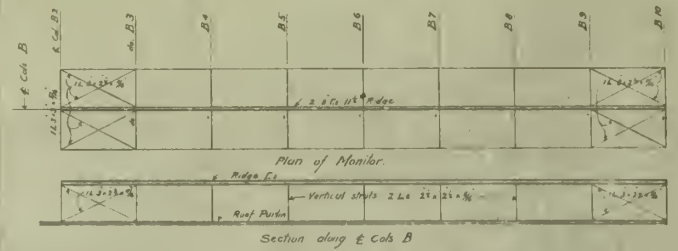

Plan of Lower Chord Bracing
Upper Chord Bracing as Noted
Plan of Bracing for Upper Chord
Details of R A 1 Reqd
Note. These braces both bent slightly to clear stack of vapor exhaust system
Detail of R "B"
Plan of Bracing for lower chord
Note All horizontal struts shown between columns and trusses to be 2 @ 3 x 3 x 1/4 unless otherwise noted. All diagonal bracing to be 1 1/2 x 1/4 unless otherwise noted
Note See detail for change of trusing in this section
Cols D.
Cols E
Cols F
Cols G
Truss
Crane Girders
Bldg Col.
Strut 7 See ckt
3 spcs = 41'-0"
3 spcs = 40'-11"
3 spcs 49'-10"
13 spcs. @ 15'-0" = 225'-0"
314
EVAPORATION HOUSE NO. 2
BUILDING
TOP AND BOTTOM CHORD BRACING
NORTH END
HOOKER ELECTROCHEMICAL CO.
NIAGARA FALLS, N.Y.
DRAWING No. 7181-58.

PLATE 2.



PLAN OF LOWER CHORD BRACING
UPPER CHORD BRACING AS NOTED



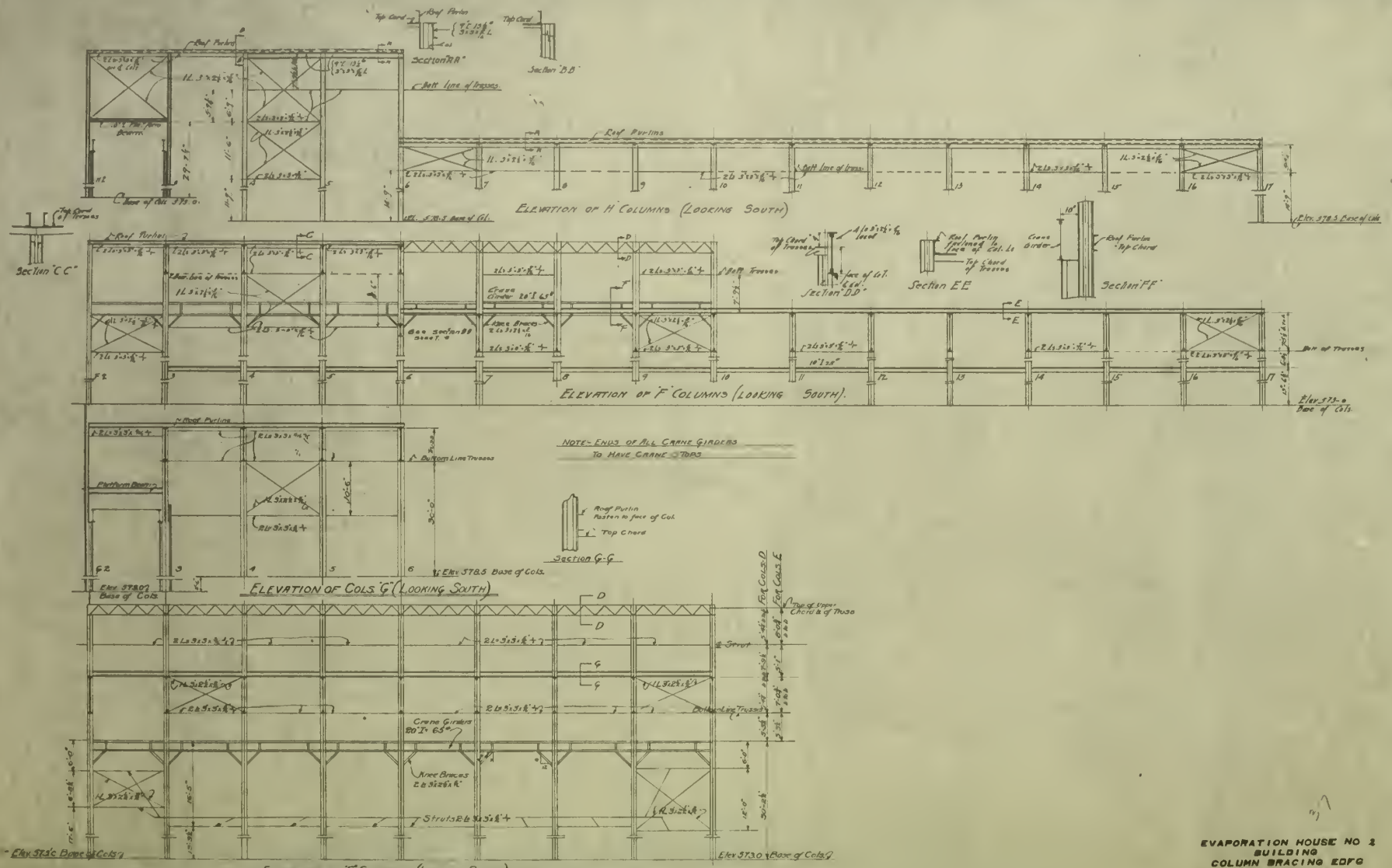
Plan of Monitor.

Section along ℄ Cols B

EVAPORATION HOUSE No. 2
BUILDING
TOP AND BOTT. CHORD BRACING
SOUTH END
NEW EVAPORATION BUILDING
HOOKER ELECTROCHEMICAL CO.
NIAGARA FALLS, N.Y.

DRAWING No 7124 SB

PLATE 3.



EVAPORATION HOUSE NO 2
BUILDING
COLUMN BRACING EDFG
HOC SR ELECTROCHEMICAL CO.
NIAGARA FALLS, N.Y.

DRAWING NO. 2655 3.8

1. Vertical roof load, 65#/sq. ft.

Wind load, 30#/sq. ft., horizontal component and vertical component, and bending.

Crane concentration.

2. Vertical roof load, 80#/sq. ft.

Crane concentration.

Bending from crane load eccentricity.

The largest result was used in proportioning the column section, which was in all cases that of the first assumption. The working stresses in the columns were as follows:

Axial compression, 16000 - 70 l/r in #/sq. in. for direct loads,

The above stress +25% when the effect of wind was taken into account.

The columns were considered fixed at the base, and were anchored in such a manner as to insure it. The horizontal shear was considered to be taken by three columns.

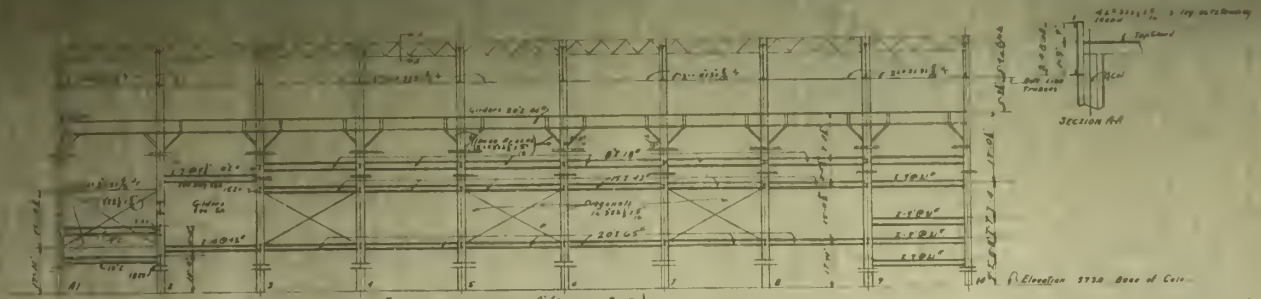
The design of a typical interior column, "B", is as follows:

Roof load--65 x 41 x 15	40,000#
Column weight--	4,000
Crane-- $\frac{11000 \times (1 + 9.6)}{15}$ + 80 x 15	18,000
Vertical component of wind	15,000
Tanks and walks	40,000
Total direct load	127,000#

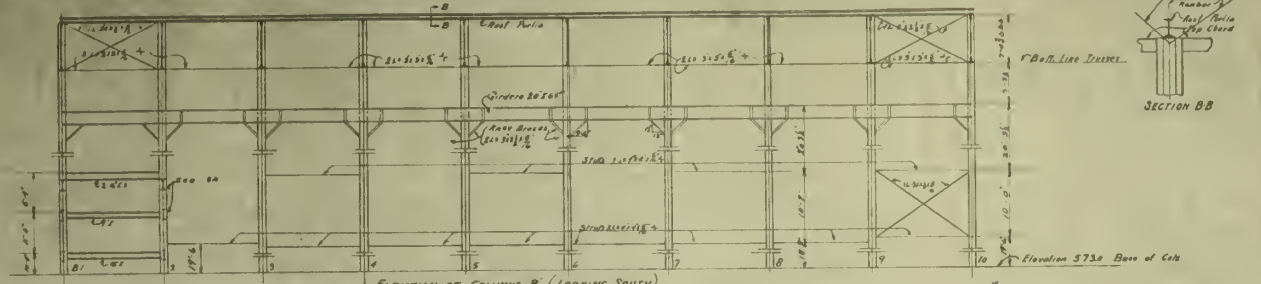
The wind horizontal shear - $H = \frac{30 \times 15}{3} \times 65 = 9750\#$.

Steel framing between the roof trusses and the base of the column made an unsupported length of 37'-0", and the point of contra-flexure was taken as one-half of this value.

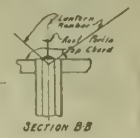
The wind moment was then, M = 9750 x 18.5 x 12 = 2,170,000#"

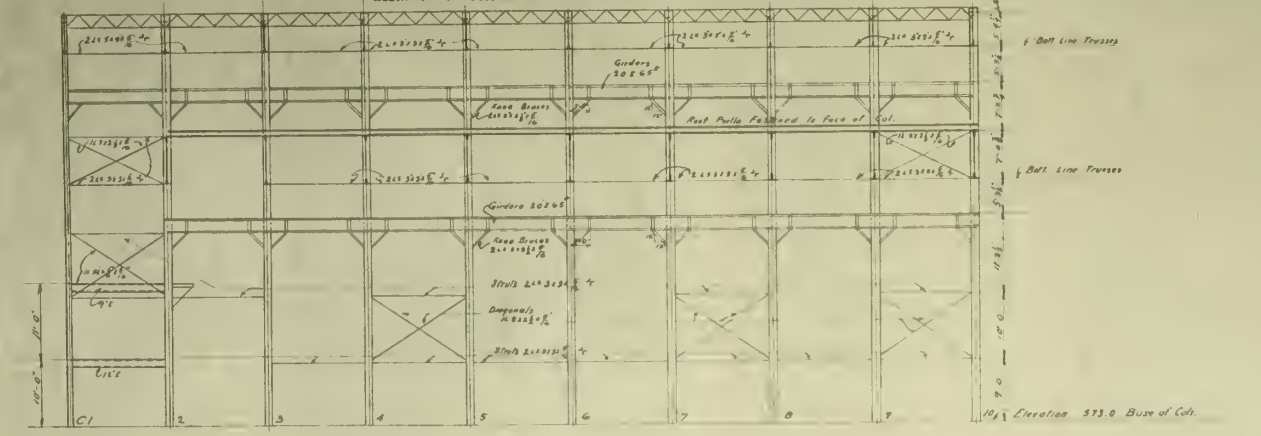


ELEVATION OF COLUMNS 'A' (LOOKING SOUTH)



ELEVATION OF COLUMNS 'B' (LOOKING SOUTH)





ELEVATION OF COLUMNS 'C' (LOOKING SOUTH)

NOTE - ENDS OF ALL CRANE GIRDERS TO HAVE CRANE STOPS

EVAPORATION NO 2
BUILDING
COLUMN BRACING
FOR COLS. A, B, & C.
HOOKER ELECTROCHEMICAL CO.
NIAGARA FALLS, N.Y.

MADE BY U.M.W. SCALE
TRACED BY BVACK DATE 8-28-16
CHECKED BY APPROVED BY

DRAWING NO 2674 SB

PLATE 5.

The section as designed is:

4Ls-6 x 4 x 7/16, 1 web pl. 24 x 3/8, 24½" back to back of Ls.

$A = 16.72 + 9.0 = 25.72$ sq. in.

$I = 16.72 \times (11.29)^2 + 432.0 + 22.0 = 2584$ in.^{4}

$S = \frac{2584.0}{12.25} = 211.0$ in.^{3}

$r = \sqrt{\frac{2584.0}{25.72}} = 10.0$ in.

Allowable $f_c = (16000 - \frac{70 \times 37 \times 13}{10.0}) \times 1.25 = 16{,}200$#/sq. in.

Actual $f_c = \frac{127{,}000}{25.72} + \frac{2{,}170{,}000}{211.0} = 15{,}100$#/sq. in.

The anchor bolts were designed to take the bending due to the wind, the unit stress used being 25,000#/sq. in. For a distance center to center of bolts of 30½"

$T = \frac{2{,}170{,}000}{30.5} = 71{,}200$#

$A = \frac{71{,}200}{25{,}000} = 2.74$ sq. in.

4-1¼" bolts were used. A 3" sleeve was provided with each anchor bolt to facilitate the erection of the columns.

Crane Runway Girders.

Hand-operated cranes of five tons capacity were provided for in four of the bays. In designing the crane runway girders impact amounting to 10% of the wheel loads was added.

Position of crane for maximum moment:

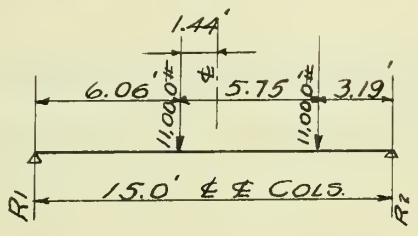


Fig. 2.

The top flange of the girder was designed for the full vertical load acting with a lateral thrust of 20% of the vertical load, the latter being taken by both girders. The allowable flange stress used was 16000 - 150 l/b + 30%, and the allowable shear on the web was 10,000#/sq. in. on the net section.

$R_1 = 11{,}000 \times \frac{(3.19 + 8.94)}{15.0} = 8{,}900\#$

$M_m = 8{,}900 \times 6.06 \times 12 = 650{,}000\#"$

Total $M_v = 650{,}000 \times 1.1 = 715{,}000\#"$

$M_l = 650{,}000 \times 0.1 = 65{,}000\#"$

$V_m = 11{,}000 \times \frac{(15.0 + 9.25)}{15.0} \times 1.1$

$= 20{,}000\#$

The section as designed is:

4Ls-5 x $3\frac{1}{2}$ x 5/16, 1 web pl. 24 x 3/8, $24\frac{1}{2}$" back to back of Ls.

Net I $= (10.24 \times 11.41^2 + 7.0 + 432.0) - (0.33 + 0.54) \times 10.25^2 = 1664.0$ in.^{4}

Section mod. S $= \frac{1664.0}{12.25} = 136.0$ in.^{3}

Top flg. I $= 5.12 \times 2.39^2 = 28.2$ in.^{4}

Section mod. S $= \frac{28.2}{5.19} = 5.24$ in.^{3}

l/b $= \frac{15 \times 12}{10.37} = 17.3$

Allowable $f_c = (16000 - 150 \times 17.3) \times 1.3 = 17{,}500\#$/sq. in.

Actual $f_c = \frac{715{,}000}{133.0} + \frac{65{,}000}{5.24} = 17{,}750\#$/sq. in.

Flange rivet spacing was governed by bearing on the 3/8" web, the allowable bearing value of each rivet being 3375# at 12,000#/sq. in.

Wheel reactions on the top flange produced a localized loading on the rivets, which was considered to be distributed over a length equal to the depth of the girder,

$w = \frac{11{,}000}{24.5} = 450\#$/linear in.

The required spacing for rivets, $s = \frac{3375}{\sqrt{(\frac{20{,}000}{20.5})^2 + (450)^2}} = 3.15"$

Accordingly a single line of rivets was sufficient to transmit the horizontal shear through the web to the support.

Intermediate stiffener angles were not required, since the ratio of the unsupported web to the thickness was $\frac{24.5 - 7.0}{.375} = 47$, the allowable value being 60. However, two stiffener angles 4 x 3 x 5/16 were provided at the knee braces.

The unit shear on the web of the girder at the column was $\frac{20,000}{(24 \times 0.375) - (2 \times 0.875)} = 2760\#/\text{sq. in.}$, which was less than the allowed value of 10,000#/sq. in.

The girders were connected to the column by a seat, which consisted of a 3/4" pl. with a shelf and stiffener angle. The web of the girder was connected to the face of the column by a diaphragm, and in addition a knee-brace of 2Ls-3 x 2½ x 5/16 was provided at the column.

Column Footings.

In designing the column footings, it was decided that it would be safe to design for the vertical reaction only, neglecting the effect of bending in the column due to the wind and the crane, since the building was wide, and the columns were well braced throughout by wind bracing, and by the super-structure for the equipment. However, the low soil pressure of 4,000#/sq. ft. was used in proportioning the base of the footing. Test pits showed the strata of red clay to be moderately dry, and about six feet thick, on a bed of hard-pan and stone. Such a foundation doubtless has a safe bearing capacity of 10,000#/sq. ft, and the value used was considered ample for the assumed loads. All footings were required to extend down one foot into this strata of red clay, which required excavation to a depth of six feet, as shown in the diagram.

All column footings were of plain concrete, except that 4-3/4" ϕ rods were placed vertically in the piers to the base of the

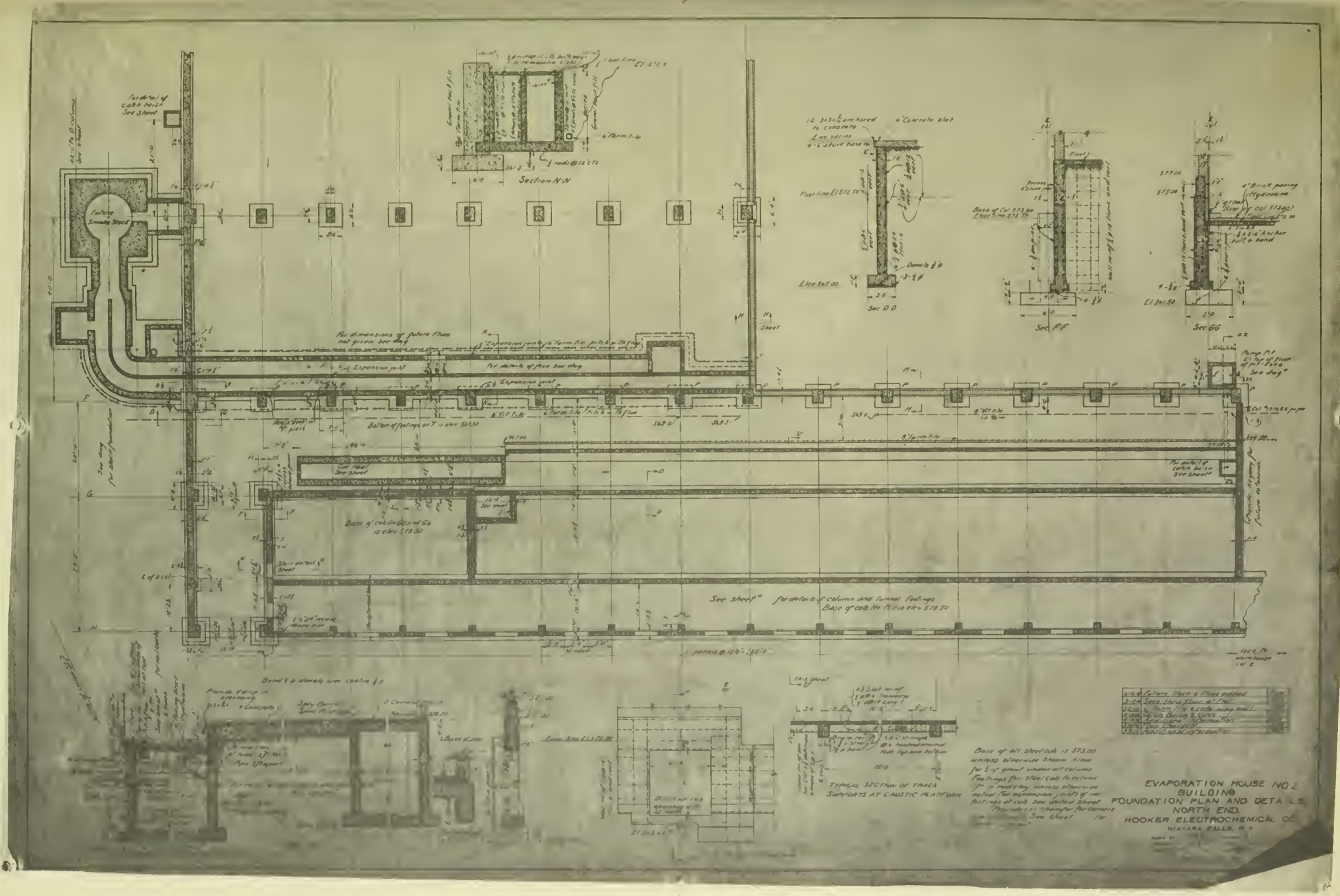

Section N-N
Sec DD
Sec FF
Sec GG
EVAPORATION HOUSE NO 2
BUILDING
FOUNDATION PLAN AND DETAILS
NORTH END.
HOOKER ELECTROCHEMICAL CO.
NIAGARA FALLS, N.Y.

PLATE 6.

column. It was decided that it would effect a great saving of time in the field and office to use footings of mass concrete, and in proportioning the base, the offsets were made about 0.75 of the thickness. The foundation plans were rushed in order to be ready to receive the steel work at the time specified for completion.

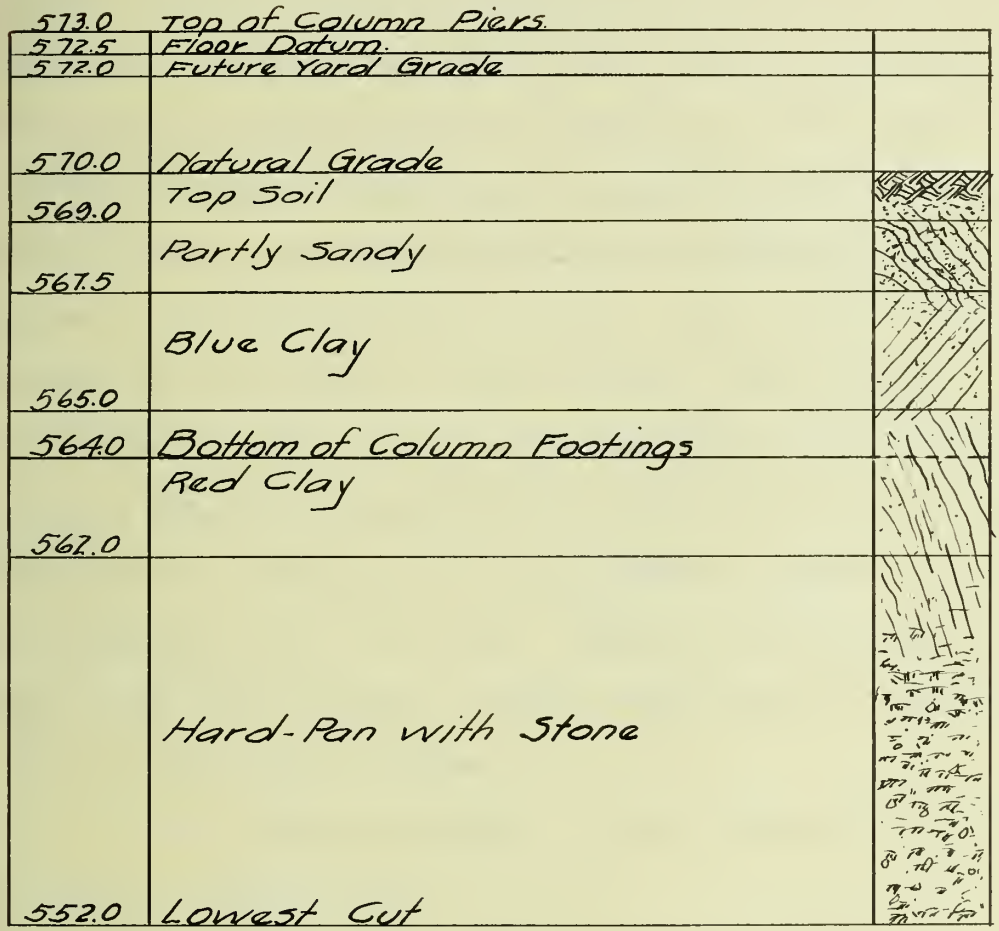


Fig. 3. Diagram of Soil Strata.

Wall Footings.

In designing the wall footings, precautions were taken to avoid unsightly cracks, as the concrete was to be carried up five feet above the future grade. The wall load was carried directly to the column footings, and expansion or settlement joints were made at each column pier. In addition, temperature reinforcing of about 0.3% was placed horizontally and vertically. This concrete was poured in freezing weather, and a critical examination of walls

Although the roof consisted of a concrete slab laid on top of the steel purlins, adequate bracing was provided in the plane of the top chord as well as that of the lower. Every other panel was braced with single angles, no rod bracing being used, as it was the experience of the Hooker Electrochemical Company that angle bracing was more satisfactory because of the positive connections. Specifications for one building erected by the Company called for an initial stress of 5000#, but this point had been so frequently neglected that the practice had been discontinued. A star strut of 2Ls-4 x 3 x 5/16 connected the braced panel points of the trusses in the braced bays, a single angle being provided in the unbraced bays to serve as a tie between the trusses. By bracing every other bay, all interior trusses were detailed exactly alike. An effort was made to make all trusses of exactly the same detail throughout the building, and the center to center of roof columns was accordingly made the same. However, through an oversight, the width of the roof columns varied, which caused a slight difference in the length of the trusses.

The loading assumed for the columns was as follows:

Roof load----80#/sq. ft.

Wind load----30#/sq. ft. on the vertical surface.

Crane concentration, including 10% for impact.

Bending from eccentricity of crane load.

It was deemed safe to neglect the bending due to the crane load eccentricity, as it is scarcely probable that the dead, snow, wind, and crane loads would be acting to their full assumed value simultaneously. Moreover, with a wind pressure of 30#/sq. ft. no snow could stay on the roof. The columns were designed for two assumptions; viz.,

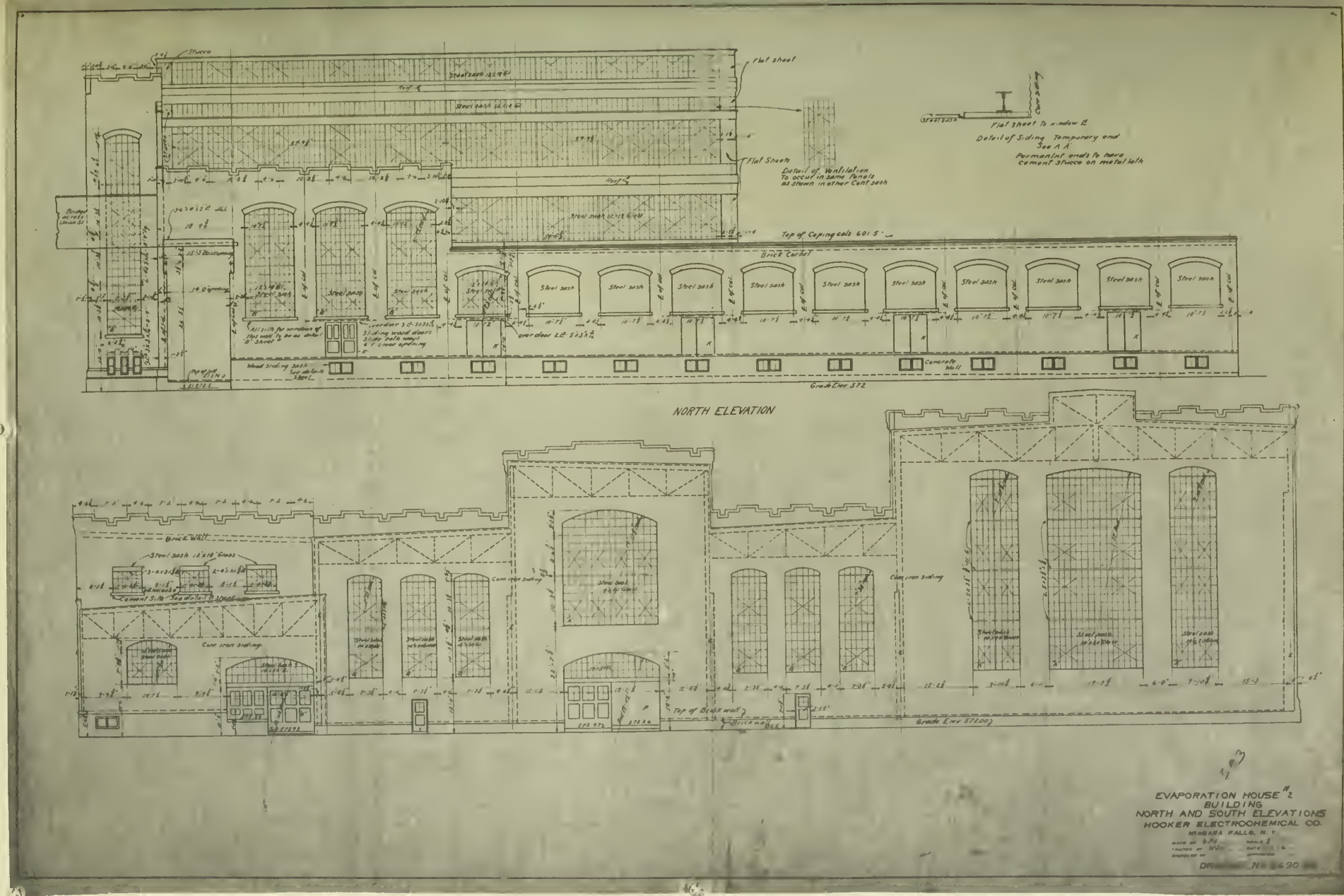
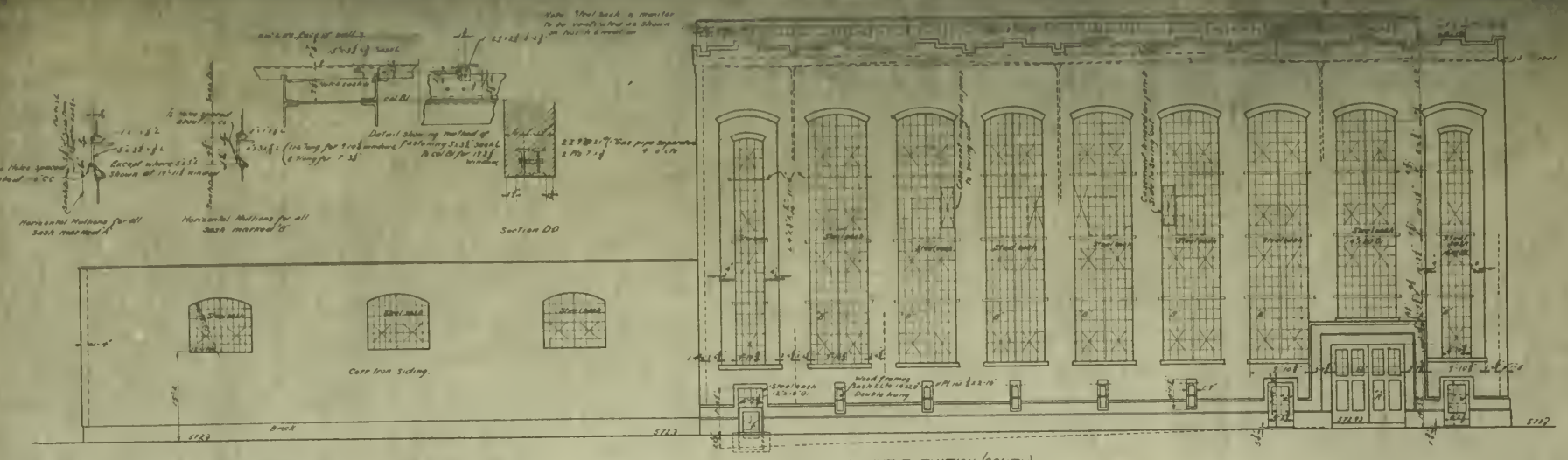

Flat sheet
Flat Sheets
Detail of Ventilation
To occur in same Panels
as shown in other Cont sash
Flat sheet to window
Detail of Siding Temporary and
See A A
Permanent ends to have
cement stucco on metal lath
Top of Coping cols 601 5
Brick Corbel
Steel sash
Concrete Wall
Grade Elev 572
NORTH ELEVATION
Brick wall
Cement Silt
Corr. iron siding
Top of Brick wall
Grade Elev 572.00
EVAPORATION HOUSE #2
BUILDING
NORTH AND SOUTH ELEVATIONS
HOOKER ELECTROCHEMICAL CO.
NIAGARA FALLS, N. Y.

PLATE 8.


Horizontal Mullions for all Sash marked A
Horizontal Mullions for all Sash marked B
Section DD
Detail showing method of Fastening Sash to Coil Bar for Window
Coal Bar
Steel Sash
Steel Lintel
Steel Jamb
Steel Mullion
Steel Transom
Steel Sill
Steel Coping
Steel Base
Steel Door
Steel Frame
Steel Gable Angle
Steel Roof Truss
Steel Purlin
Steel Girt
Steel Column
Steel Beam
Steel Rafter
Steel Brace
Steel Plate
Steel Angle
Steel Channel
Steel Tee
Steel Bar
Steel Rod
Steel Strap
Steel Hinge
Steel Latch
Steel Lock
Steel Key
Steel Screw
Steel Bolt
Steel Nut
Steel Washer
Steel Rivet
Steel Weld
Steel Paint
Steel Primer
Steel Finish
Steel Coat
Steel Layer
Steel Sheet

in July revealed no cracks whatsoever. For all concrete placed in cold weather, precautions were taken to avoid freezing, by heating the gravel, and by covering the concrete with a thick layer of straw.

Permanent Walls.

All permanent exterior walls were of brick, and were made of such a thickness as to be self-supporting. The brick used was a #1 shale brick laid in #4 mortar, the mixture being one part portland cement, one part lime, and six parts sand.. The brick was laid during warmer weather, and no special care was necessary to protect it. In laying the brickwork around the columns, rods run through the column flanges and laid in the joints were provided about every four feet, to secure a good bond and thus stiffen the wall. Openings were left in the brick work for doors, but the steel sash was erected first, and the brick laid around it.

Temporary Walls.

On the sides and ends where future extension of the building was proposed, the walls were of corrugated steel fastened to steel girts. These girts, in general, were a channel section connected to the main building columns. In the wide bays, wind bracing columns of 10" and 12" I beam sections supported the girts, and were connected to the lower chord of the roof trusses. All siding, girts, and columns were designed to withstand a horizontal wind pressure of 30#/sq. ft.

Windows.

It was very essential to obtain as much light and ventilation as possible, and in the design of the building special attention was paid to this important feature. Practically all windows were of steel sash, glazed with $\frac{1}{4}$" ribbed wire glass,

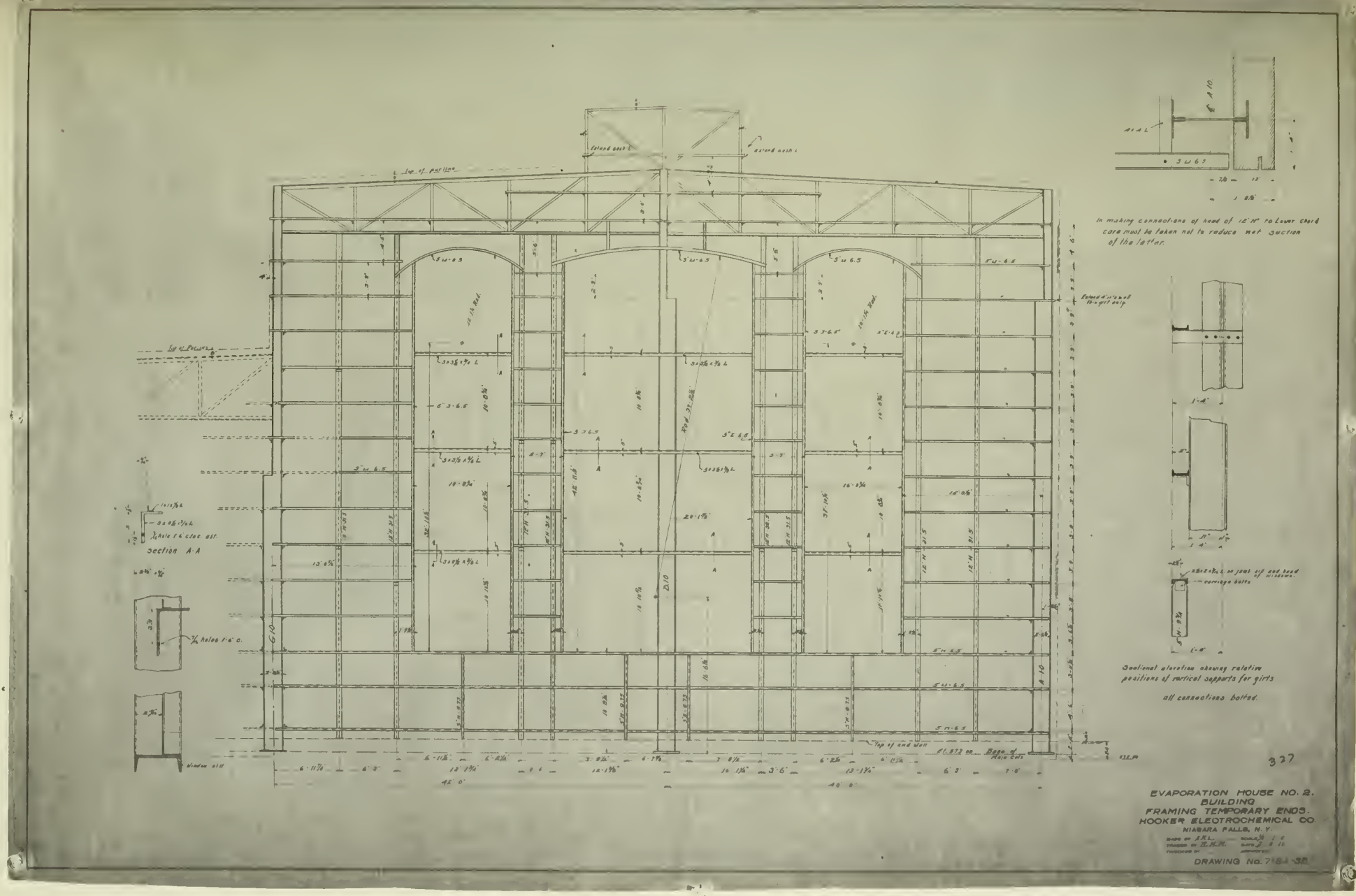

Section A-A
In making connections of head of 12"H. to Lower chord care must be taken not to reduce net section of the latter.
Sectional elevation showing relative positions of vertical supports for girts
all connections bolted.
337
EVAPORATION HOUSE NO. 2.
BUILDING
FRAMING TEMPORARY ENDS.
HOOKER ELECTROCHEMICAL CO.
NIAGARA FALLS, N.Y.
DRAWING No. 7181-32

PLATE 10

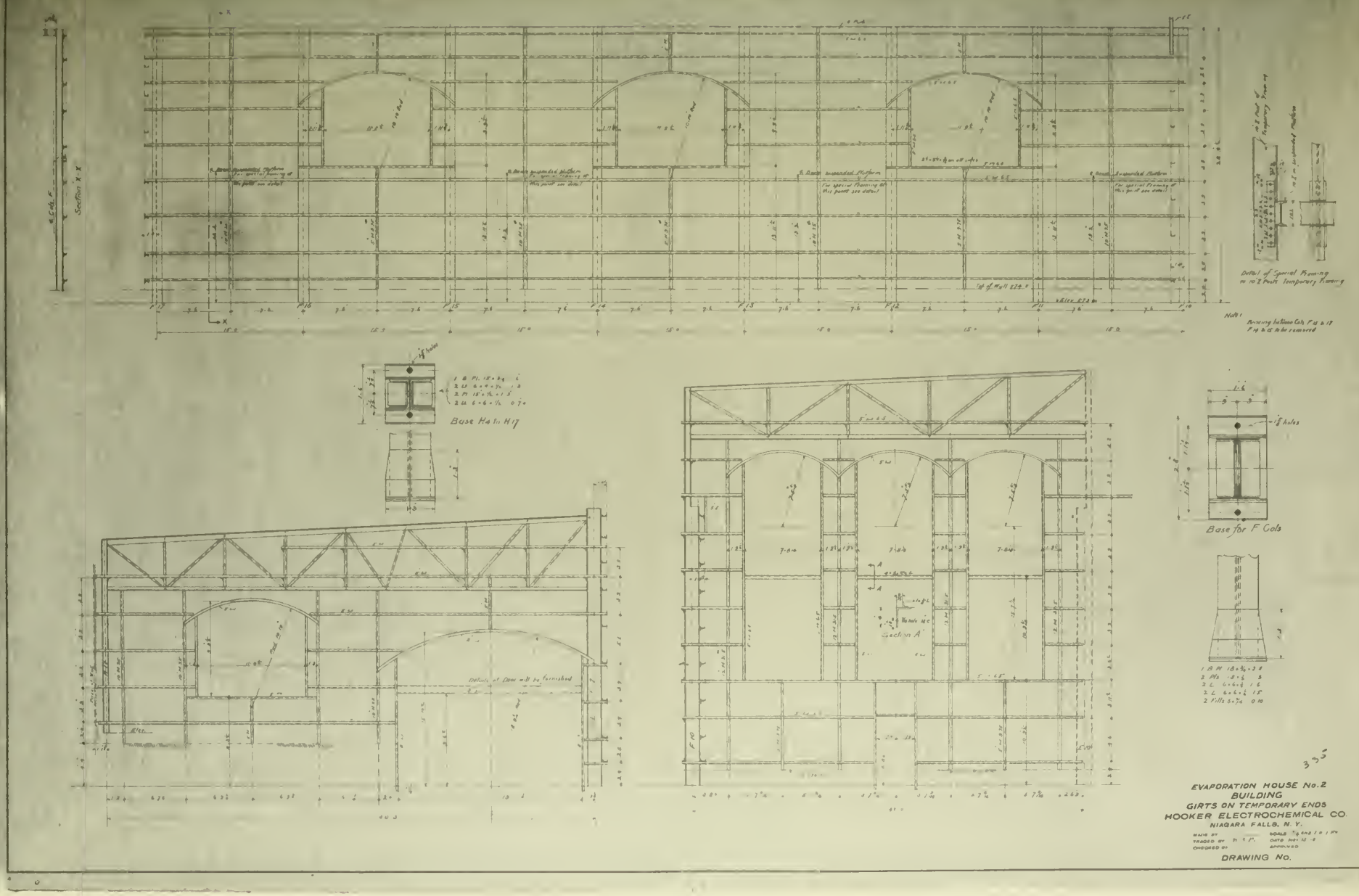

Section X-X
Base H4 to H17
Base for F Cols
Section A
Detail of Special Framing
Note:
EVAPORATION HOUSE No. 2
BUILDING
GIRTS ON TEMPORARY ENDS
HOOKER ELECTROCHEMICAL CO.
NIAGARA FALLS, N. Y.
DRAWING No.

PLATE II.

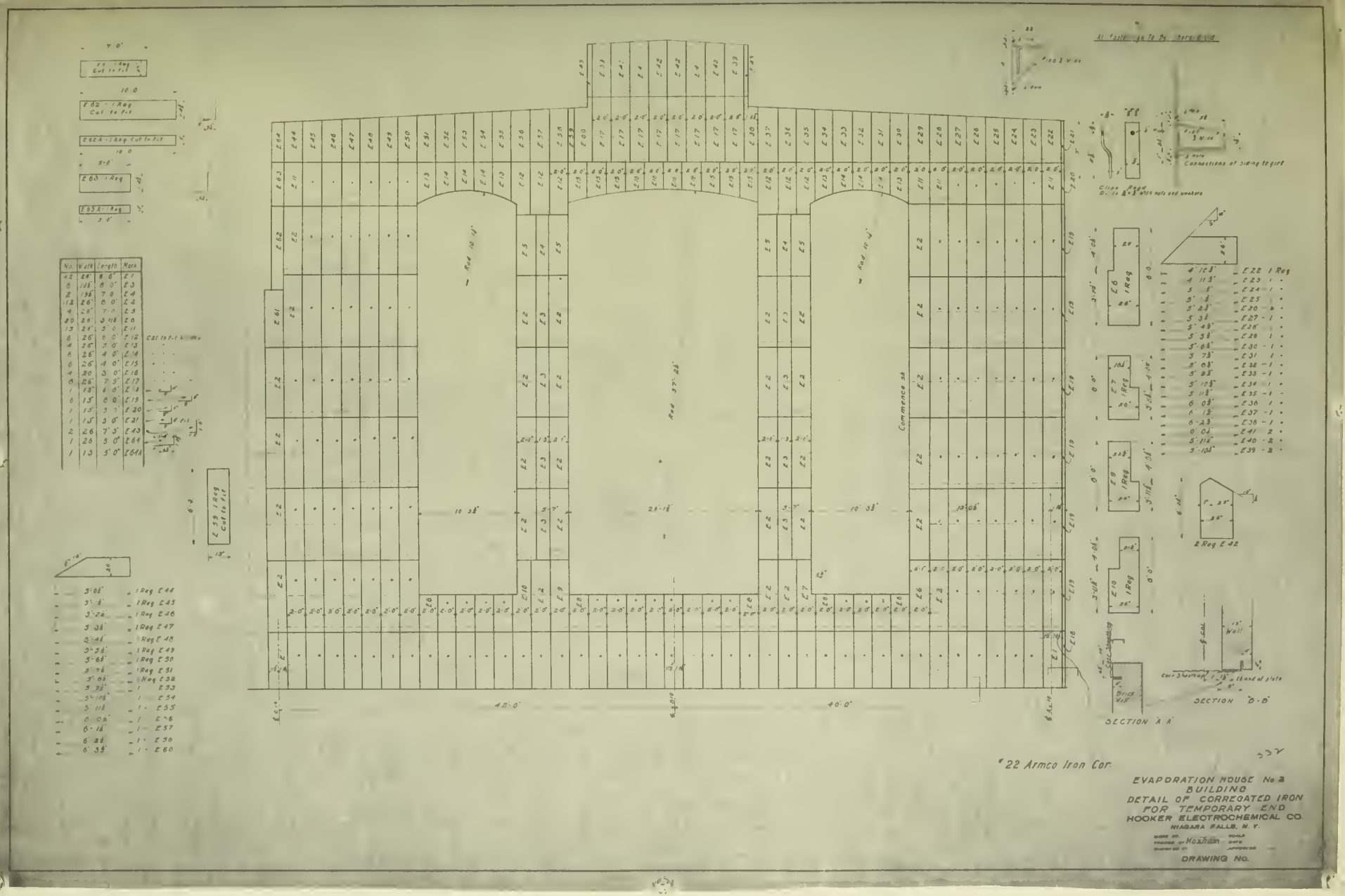

EVAPORATION HOUSE No 2
BUILDING
DETAIL OF CORREGATED IRON
FOR TEMPORARY END
HOOKER ELECTROCHEMICAL CO.
NIAGARA FALLS, N. Y.
DRAWING No.
SECTION A-A
SECTION B-B
#22 Armco Iron Cor.

PLATE 12.

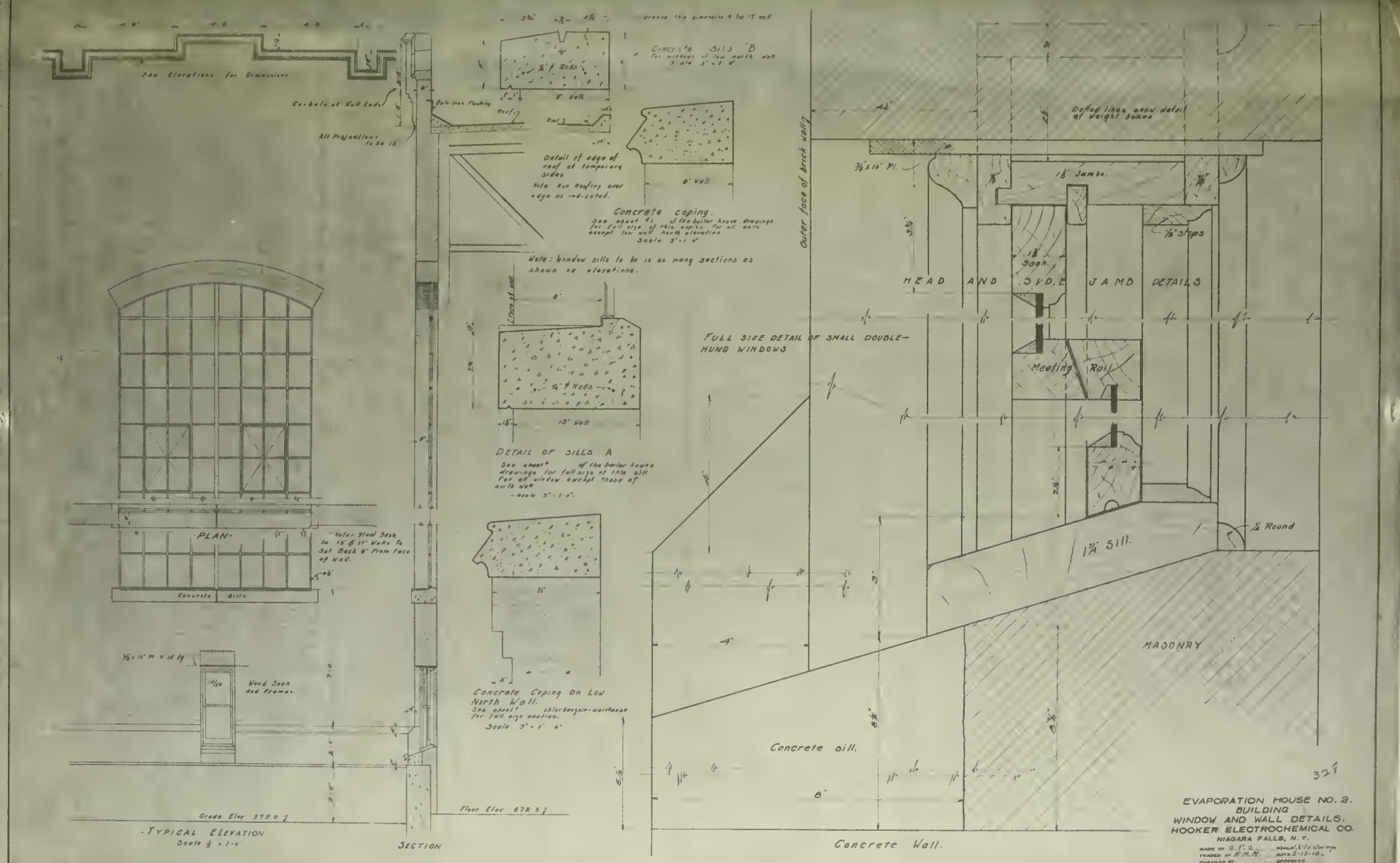
14" x 20" in size. On account of the height of the sash, horizontal steel angle mullions were placed between the sash units, and connected to the columns. The sash in the temporary sides was designed with the end in view of using it in the permanent walls of the proposed future construction. Ventilating sash amounting to about fifteen percent of the total sash area was provided in all walls and monitors. Arched window heads of three row-lock courses of brick, with a radius equal to the width of the opening, eliminated steel lintels for the windows. It is doubtful if this method is more economical than to provide steel lintels, on account of the cost of the arch centering, but it was used primarily for architectural reasons.

Doors.

All exterior doors in the building were made of white pine stiles and rails with 7/8" ceiling panels, and were of three types; swinging car doors, passage doors, and sliding doors for the loading platform. The car doors were made sufficiently wide to obtain a clearance of 4'-10" from the center of the track for the standard truck of the Hooker Electrochemical Company. The passage doors were made 3'-0" and 4'-0" wide and 7'-0" high, and swung outward, to conform to the New York State laws. Sliding doors for the loading platform were made 8'-0" x 10'-0", and so spaced as to register with a train of cars on the loading track.

Roof Construction.

All roofs were covered with five-ply Barrett Specification roofing laid directly on top of the concrete slab or cinder concrete crickets. Care was taken in making the detail drawings of the roof, to secure first class flashing, for it was realized that neglect of this point usually results in considerable annoyance, if not actual



See Elevations for Dimensions
Corbels of Wall Ends
All Projections to be 1½"
Gate Iron Flashing
Roof
Concrete Sills "B"
For windows of low north wall
Scale 3" = 1'-0"
Detail of edge of roof at temporary sides
Note Roofing over edge as indicated.
Concrete coping.
See sheet #1 of the boiler house drawings for full size of this coping. For all walls except low wall north elevation
Scale 3" = 1'-0"
Note: Window sills to be in as many sections as shown on elevations.
DETAIL OF SILLS A
See sheet of the boiler house drawings for full size of this sill for all window except those of north wall
- scale 3" = 1'-0"
Concrete Coping On Low North Wall.
See sheet chlorbenzene-warehouse for full size section.
Scale 3" = 1'-0"
PLAN
Concrete Sills
Wood Sash And Frames.
Grade Elev 572.0
Floor Elev 572.5
TYPICAL ELEVATION
Scale ½" = 1'-0"
SECTION
Outer face of brick wall
Dotted lines show detail of weight boxes
HEAD AND SIDE JAMB DETAILS
Meeting Rail
1¾" Sill.
¼" Round
MASONRY
FULL SIZE DETAIL OF SMALL DOUBLE-HUNG WINDOWS
Concrete sill.
Concrete Wall.
EVAPORATION HOUSE NO. 2.
BUILDING
WINDOW AND WALL DETAILS.
HOOKER ELECTROCHEMICAL CO.
NIAGARA FALLS, N. Y.
DRAWING No. 7184 SB.

PLATE 13.

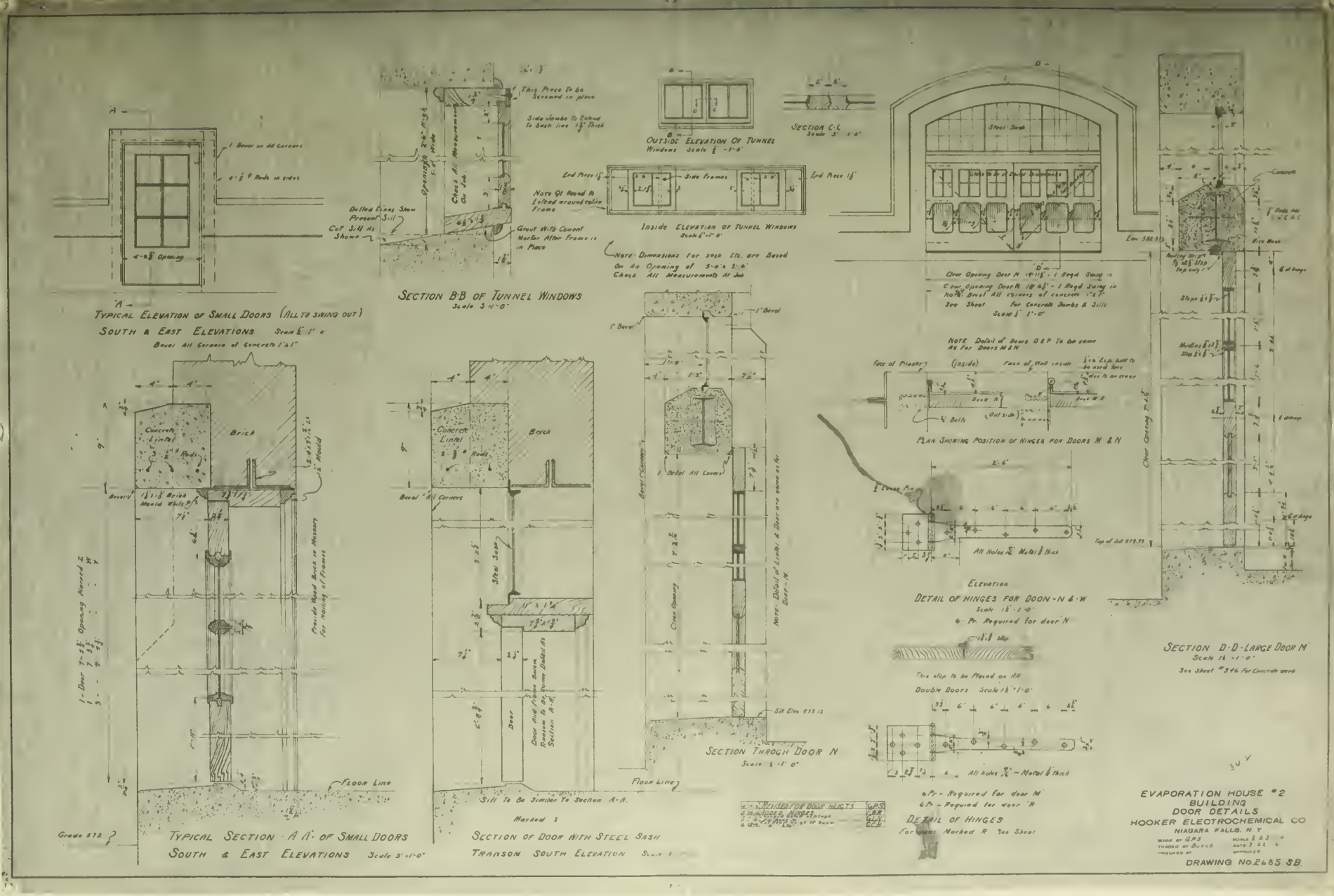

TYPICAL ELEVATION OF SMALL DOORS (ALL TO SWING OUT)
SOUTH & EAST ELEVATIONS
SECTION B-B OF TUNNEL WINDOWS
OUTSIDE ELEVATION OF TUNNEL WINDOWS
SECTION C-C
INSIDE ELEVATION OF TUNNEL WINDOWS
PLAN SHOWING POSITION OF HINGES FOR DOORS M & N
ELEVATION
DETAIL OF HINGES FOR DOOR-N & W
SECTION D-D-LARGE DOOR M
SECTION THROUGH DOOR N
TYPICAL SECTION A-A OF SMALL DOORS
SOUTH & EAST ELEVATIONS
SECTION OF DOOR WITH STEEL SASH
TRANSOM SOUTH ELEVATION
DETAIL OF HINGES
EVAPORATION HOUSE #2
BUILDING
DOOR DETAILS
HOOKER ELECTROCHEMICAL CO
NIAGARA FALLS, N.Y.
DRAWING No. 2685 SB.

PLATE 14

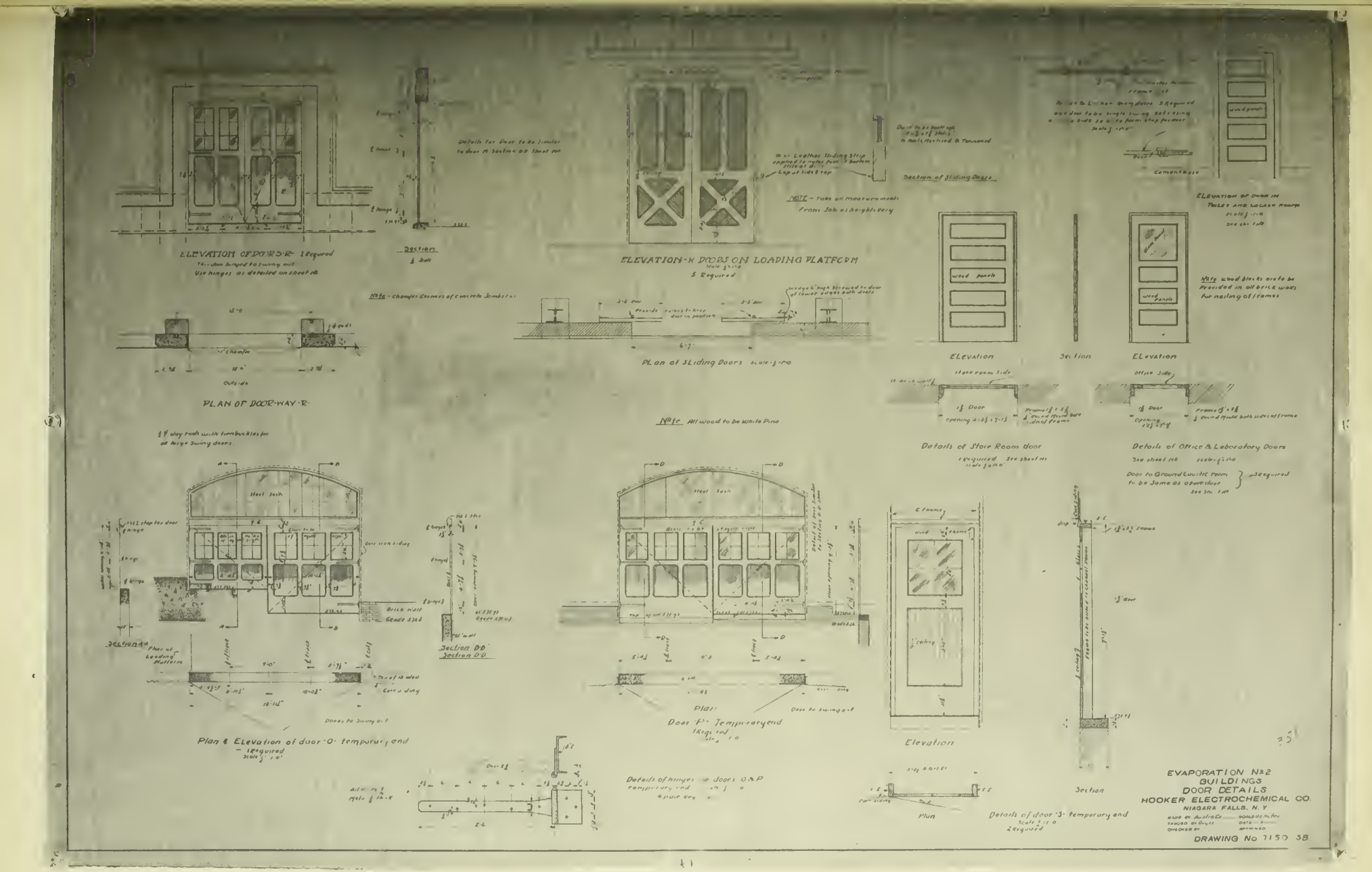

ELEVATION OF DOORS R. 1 Required
Section
PLAN OF DOOR-WAY R.
ELEVATION K DOORS ON LOADING PLATFORM
5 Required
Section of Sliding Doors
NOTE – Take all measurements from Job as heights vary
Plan of Sliding Doors
ELEVATION OF DOOR IN TOILET AND LOCKER ROOMS
Elevation
Section
Elevation
Details of Store Room door
Details of Office & Laboratory Doors
All wood to be White Pine
Plan & Elevation of door O temporary end
Section AA
Section BB
Section CC
Plan
Door P temporary end
Elevation
Section
Plan
Details of door S temporary end
Details of hinges for doors O & P
EVAPORATION No 2
BUILDINGS
DOOR DETAILS
HOOKER ELECTROCHEMICAL CO.
NIAGARA FALLS, N.Y.
DRAWING No 7150 38

PLATE 15.

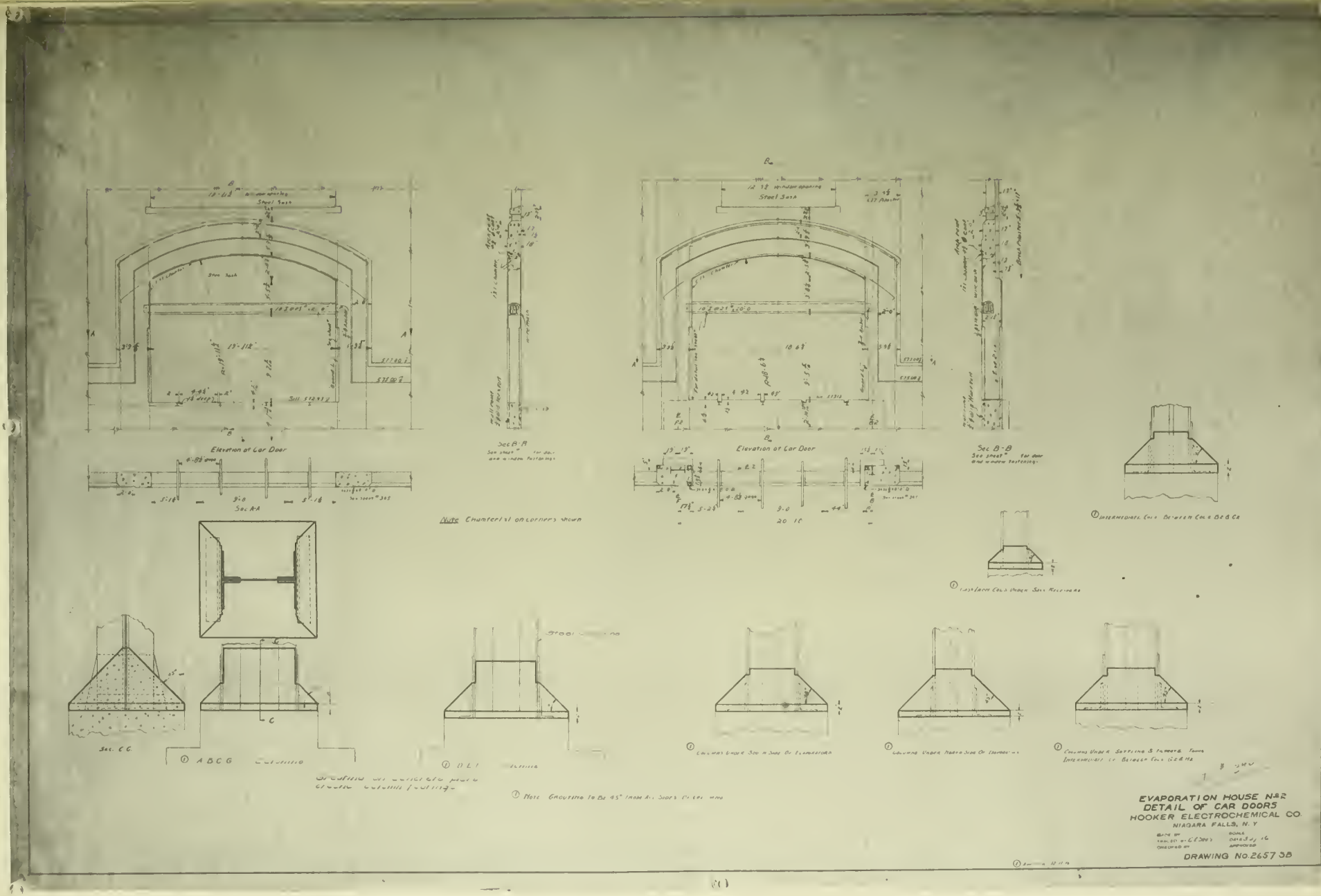

Elevation of Car Door
Sec A-A
Sec B-B
Elevation of Car Door
Sec B-B
Note Chamfer 1 on corners shown
Sec. C C
A B C G
Note Grouting to be 45° from all sides of columns
EVAPORATION HOUSE No 2
DETAIL OF CAR DOORS
HOOKER ELECTROCHEMICAL CO.
NIAGARA FALLS, N. Y
DRAWING No. 2657 SB

PLATE 16.

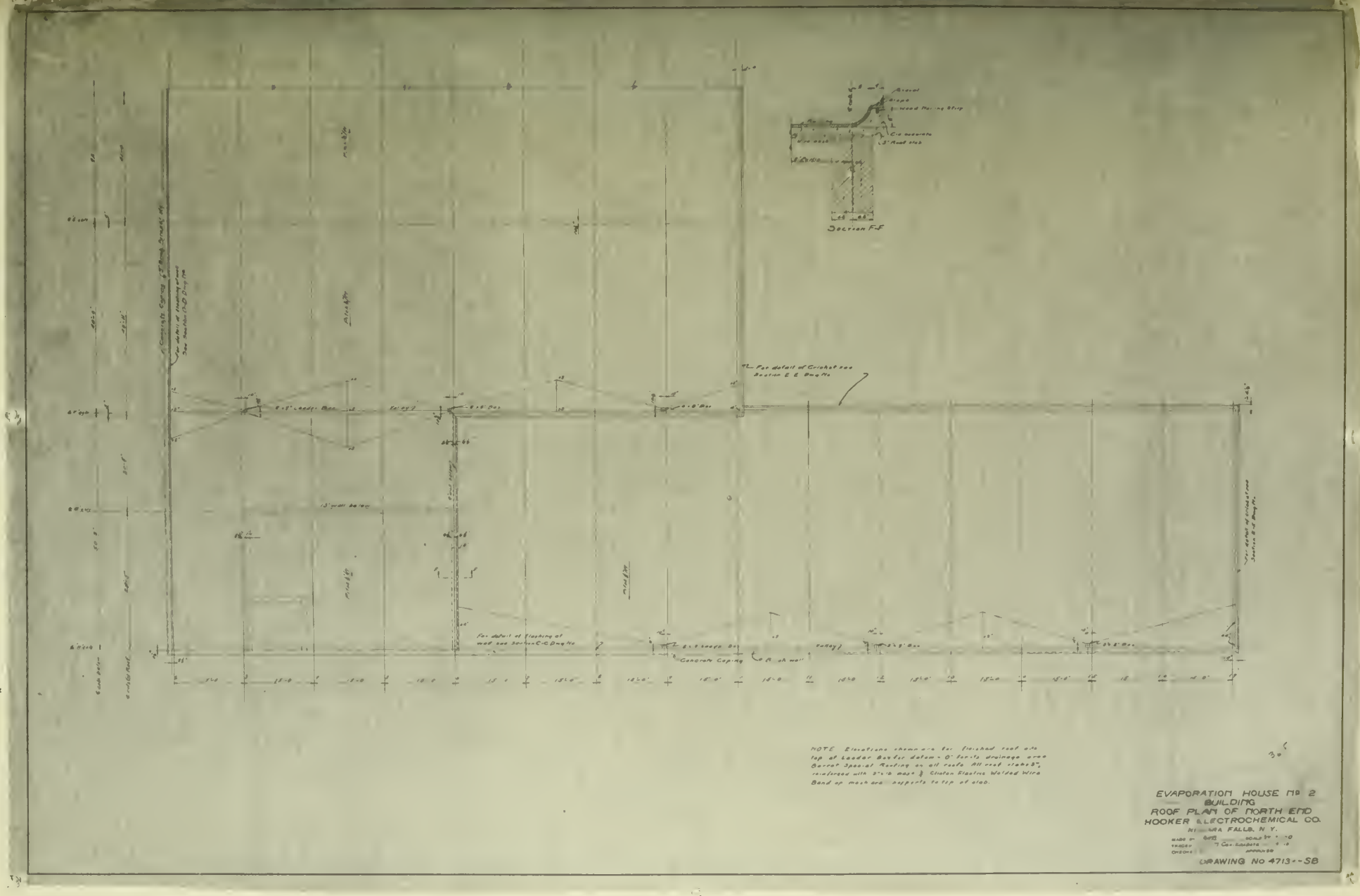

Section F-F
Concrete Coping
NOTE Elevations shown are for finished roof slab
EVAPORATION HOUSE No 2
BUILDING
ROOF PLAN OF NORTH END
HOOKER ELECTROCHEMICAL CO.
NIAGARA FALLS, N.Y.
DRAWING No 4713--SB

PLATE 17.

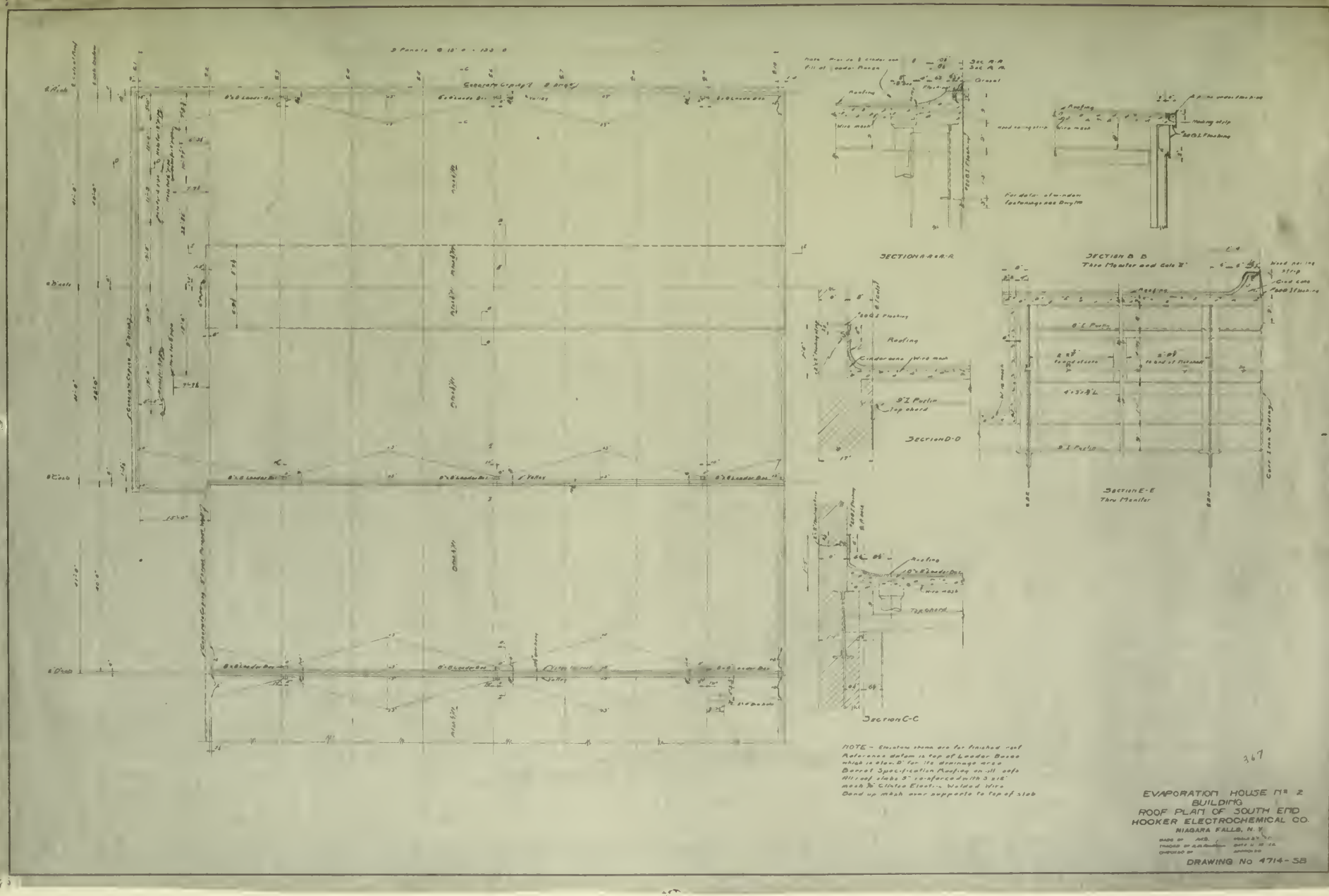

SECTION A-A & A-A
SECTION B-B
Thru Monitor and Gate "B"
SECTION D-D
SECTION E-E
Thru Monitor
SECTION C-C
NOTE - Elevations shown are for finished roof
Reference datum is top of Leader Basin
which is elev. 0' for its drainage area
Barrel Specification Roofing on all roofs
All roof slabs 3" re-inforced with 3 x 12"
mesh 1/8" Clinton Electric Welded Wire
Bend up mesh over supports to top of slab
EVAPORATION HOUSE No 2
BUILDING
ROOF PLAN OF SOUTH END
HOOKER ELECTROCHEMICAL CO.
NIAGARA FALLS, N. Y.
DRAWING No 4714-SB

PLATE 18.

LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

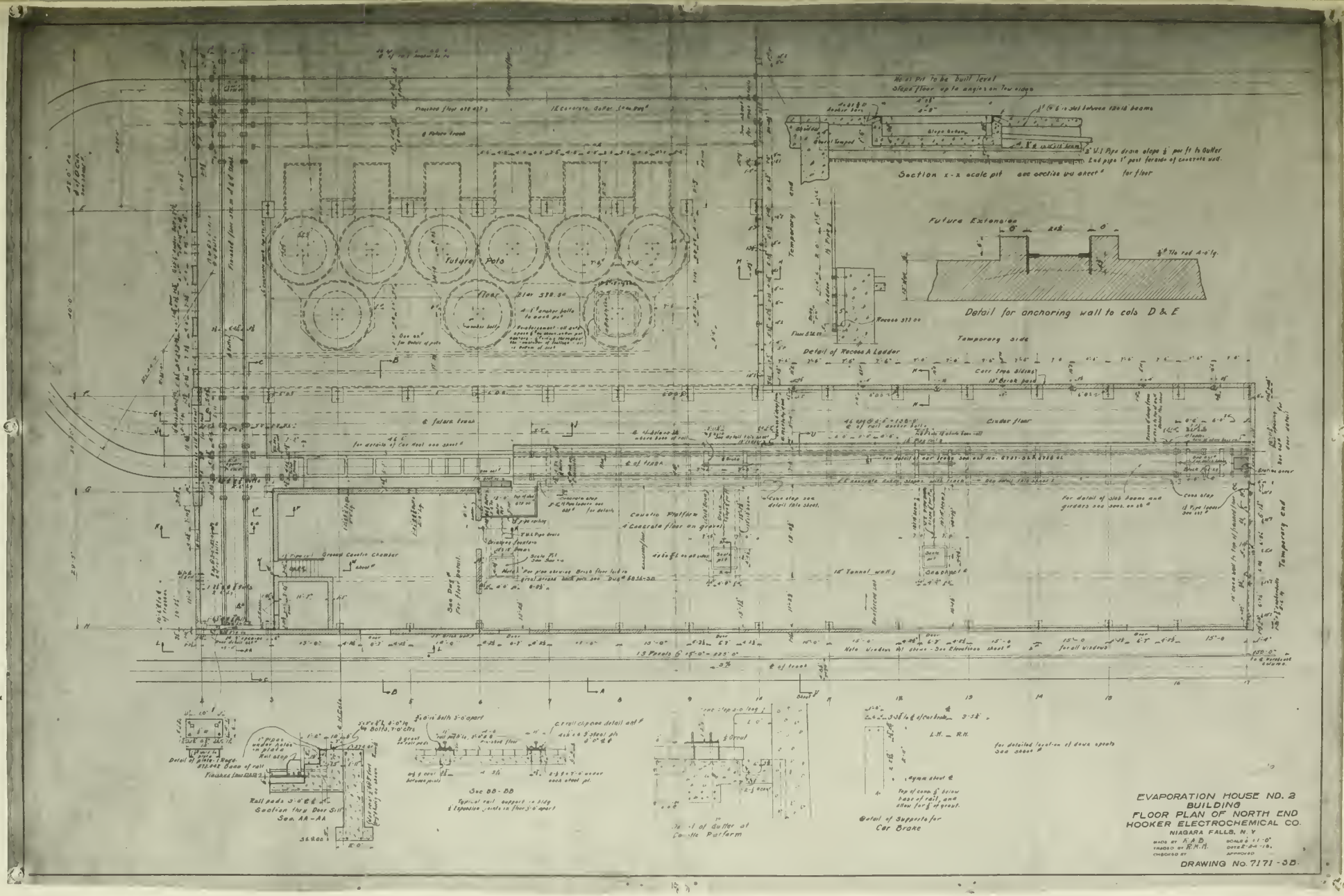

Section x-x scale pit
Future Extension
Detail for anchoring wall to cols D & E
Temporary side
Detail of Recess & Ladder
Future Pots
Cinder floor
Caustic Platform
Temporary end
Section thru Door Sill
Detail of Supports for Car Brake
EVAPORATION HOUSE NO. 2
BUILDING
FLOOR PLAN OF NORTH END
HOOKER ELECTROCHEMICAL CO.
NIAGARA FALLS, N. Y.
DRAWING No. 7171-3B.

PLATE 19.

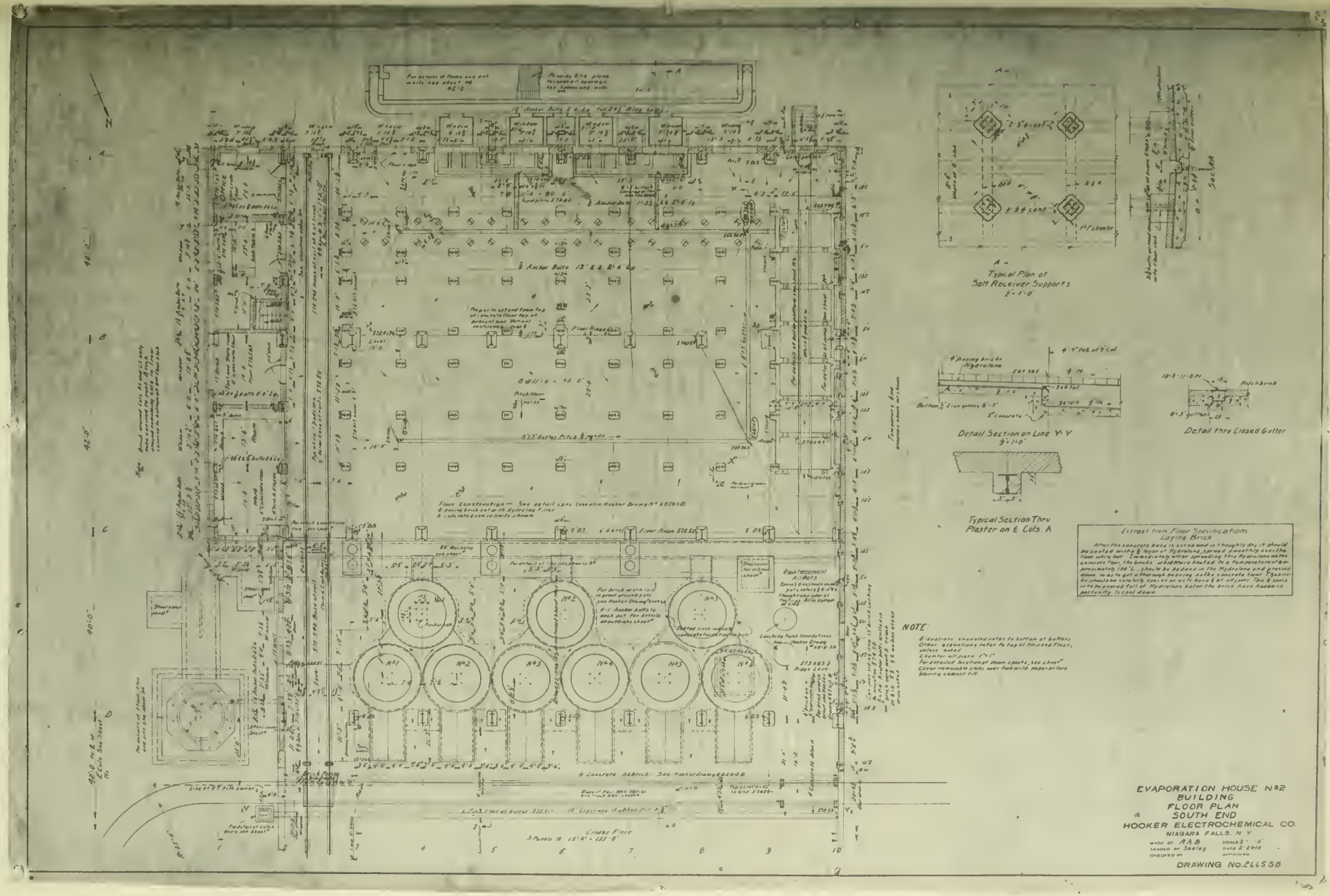

Typical Plan of Salt Receiver Supports
Detail Section on Line Y-Y
Detail thru Closed Gutter
Typical Section Thru Plaster on E. Cols. A
Extract from Floor Specifications Laying Brick
NOTE
EVAPORATION HOUSE No2 BUILDING FLOOR PLAN SOUTH END
HOOKER ELECTROCHEMICAL CO.
NIAGARA FALLS, N.Y.
DRAWING No. 26655B

PLATE 20.

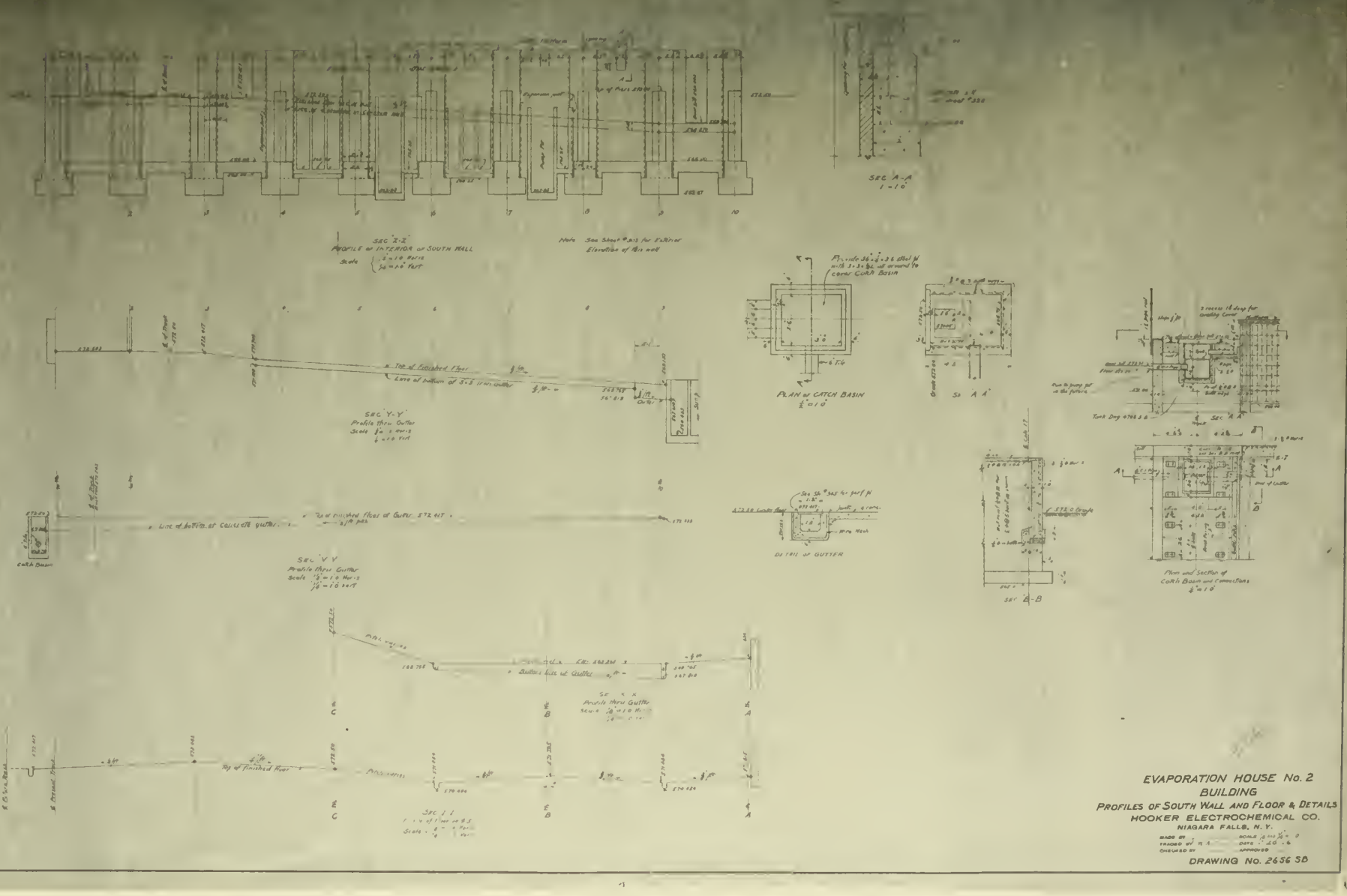

SEC Z-Z
PROFILE OF INTERIOR OF SOUTH WALL
SEC A-A
SEC Y-Y
Profile thru Gutter
SEC V-V
Profile thru Gutter
PLAN of CATCH BASIN
DETAIL of GUTTER
SEC B-B
Plan and Section of
CATCH BASIN and Connections
SEC X-X
Profile thru Gutter
SEC I-I
EVAPORATION HOUSE No. 2
BUILDING
PROFILES OF SOUTH WALL AND FLOOR & DETAILS
HOOKER ELECTROCHEMICAL CO.
NIAGARA FALLS, N.Y.
DRAWING No. 2656 SB

PLATE 21

loss. At the walls the roofing was carried up for a distance of about 12" above the slab, and cap flashing of #20 gage galvanized iron, inserted in the joints of the brick, was brought down for a distance of 6" over the roofing, the whole then being fastened with sherardized nails to a nailing strip, anchored in the wall.

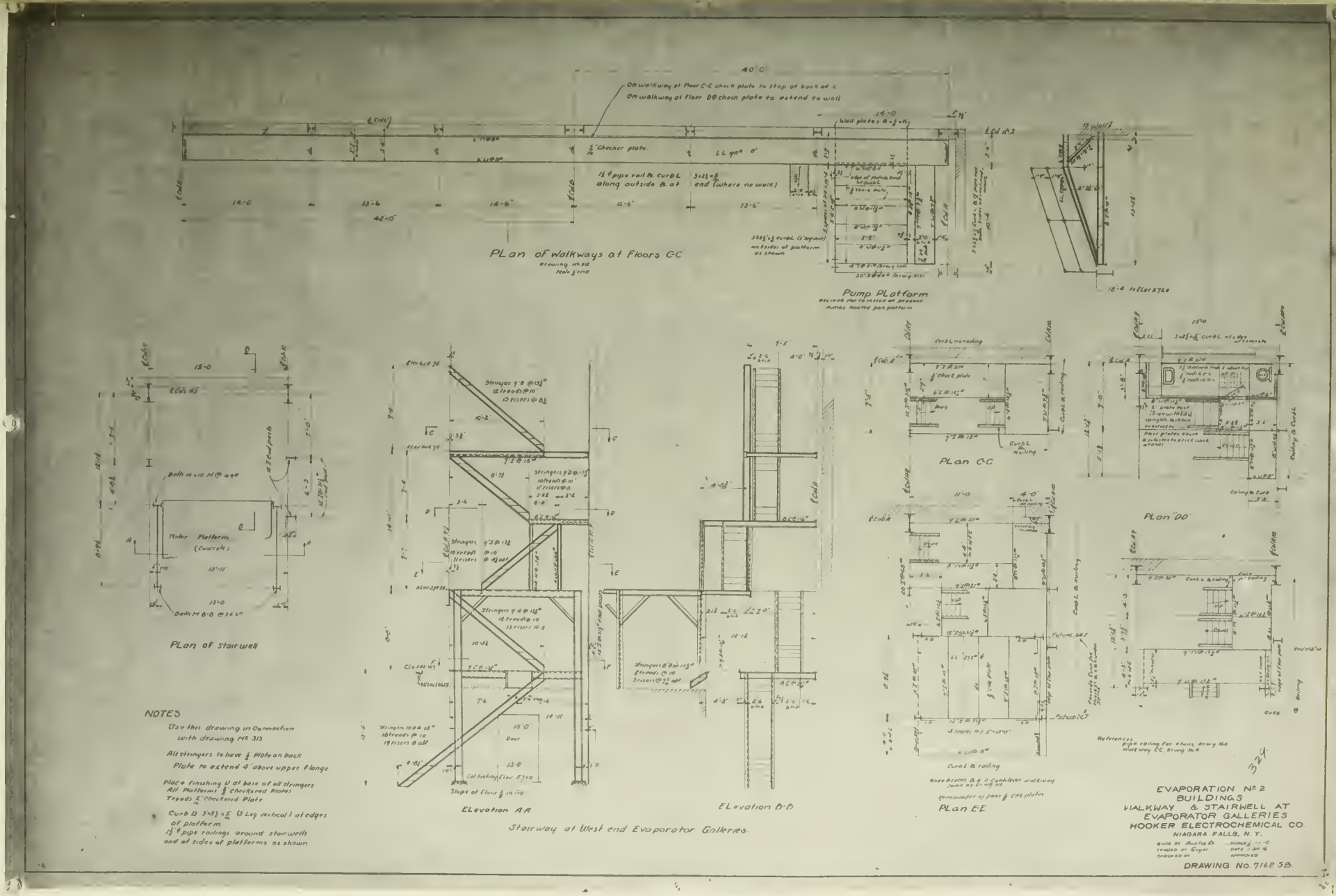
The Floor.

The permanent floor was designed to resist as much as possible the action of the caustic soda. It consisted of a sub-grade of tamped cinders 6" thick, on which was poured a 6" plain concrete slab of a 1:8 cement and gravel mixture. The concrete was allowed to set about a week, and then a 3/8" layer of "Hydrolene" was poured while hot, and spread evenly over the floor. Immediately Metropolitan vitrified paving blocks, heated to a temperature of 100°C., were imbedded in the "Hydrolene", and pressed down to an even bearing. Lugs on the bricks made joints about $\frac{1}{4}$" wide, which were filled with the "Hydrolene", the whole surface then being mopped and made smooth. The floor filler,"Hydrolene" used was a manufactured product, and from previous experience had proven satisfactory.

The caustic soda in the tanks above frequently overflowed onto the floor, and to recover this the floors were given a minimum slope of 3/8" per ft. to a water-tight wrought iron gutter draining to the caustic recovery pits on a slope of 3/8" per ft. This gutter was made of 3/16" wrought iron with welded joints, and so placed in the floor as to be easily removed.

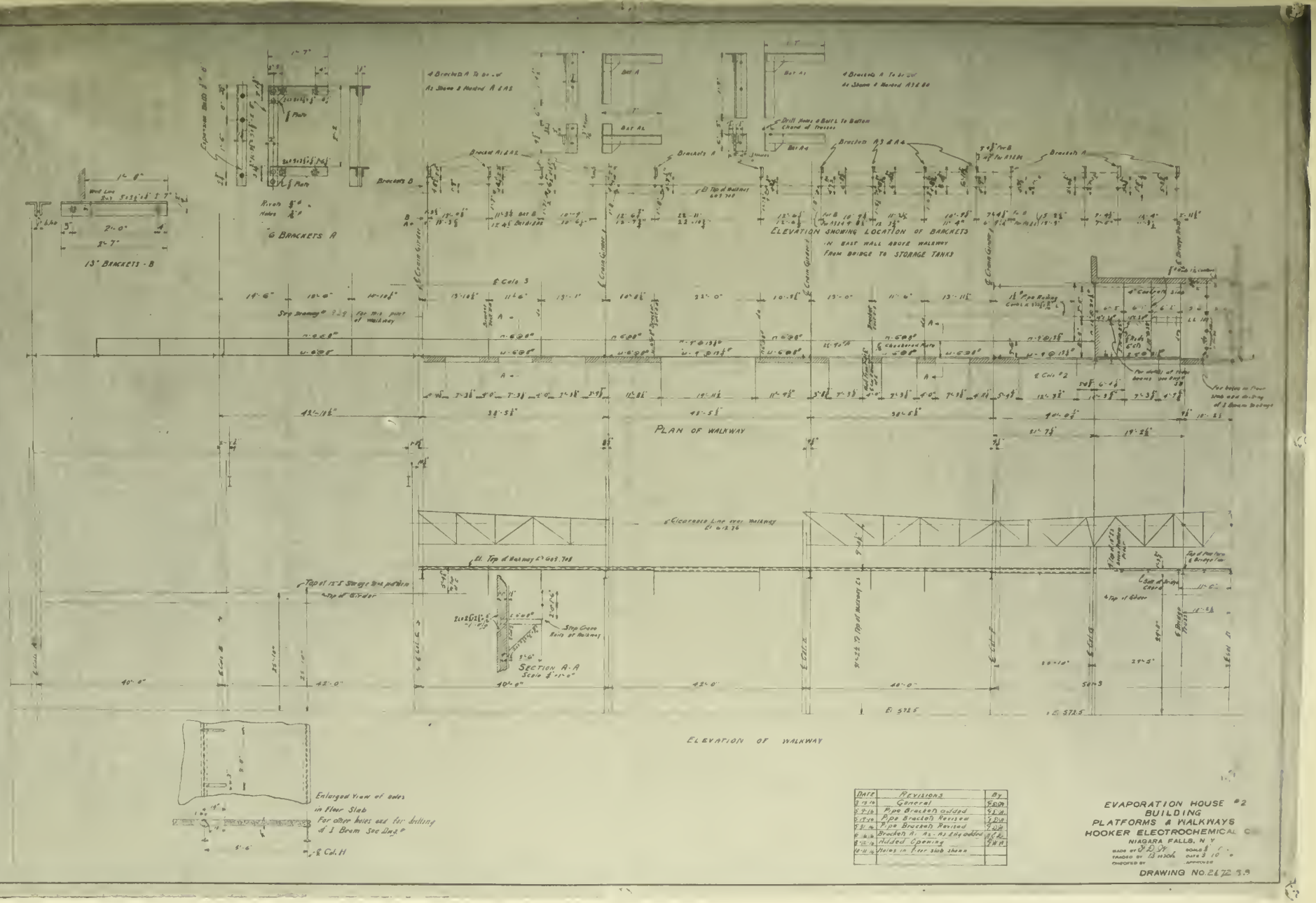
Over-head Walks and Platforms.

For the operation of the equipment above the floor, stairways, walks, and platforms were provided. In general, these were of 5/16" and 3/8" checker plates, bolted to the steel work, and were designed for a live load of 75#/sq. ft., uniformly distributed. Two



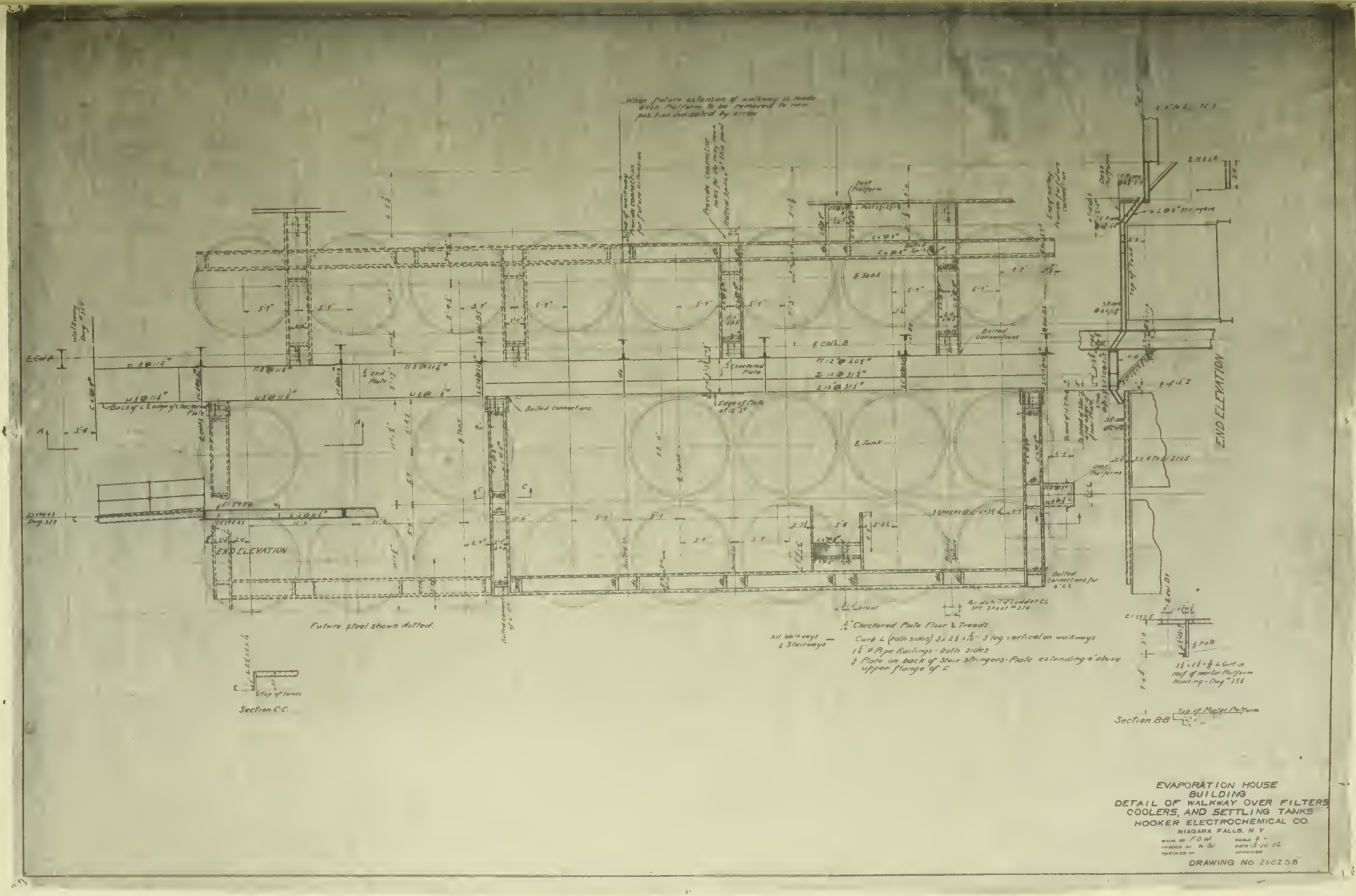
PLan of Walkways at Floors C-C
Pump PLatform
PLan of Stairwell
Motor Platform (Concrete)
ELevation A-A
ELevation B-B
Stairway at West end Evaporator Galleries.
PLan C-C
PLan DD
PLan E-E
NOTES
Use this drawing in Connection with drawing No. 313
All stringers to have ¼" Plate on back
Plate to extend 4" above upper flange
Place finishing ∪ at base of all stringers
All Platforms ⅜" Checkered Plates
Treads ⅝" Checkered Plate
Curb ∪ 3"x2½"x⅝" (3 Leg vertical) at edges of platform
1½" ϕ pipe railings around stairwells and at sides of platforms as shown
EVAPORATION No. 2
BUILDINGS
WALKWAY & STAIRWELL AT
EVAPORATOR GALLERIES
HOOKER ELECTROCHEMICAL CO.
NIAGARA FALLS, N. Y.
DRAWING No. 7162 SB.

PLATE 22.



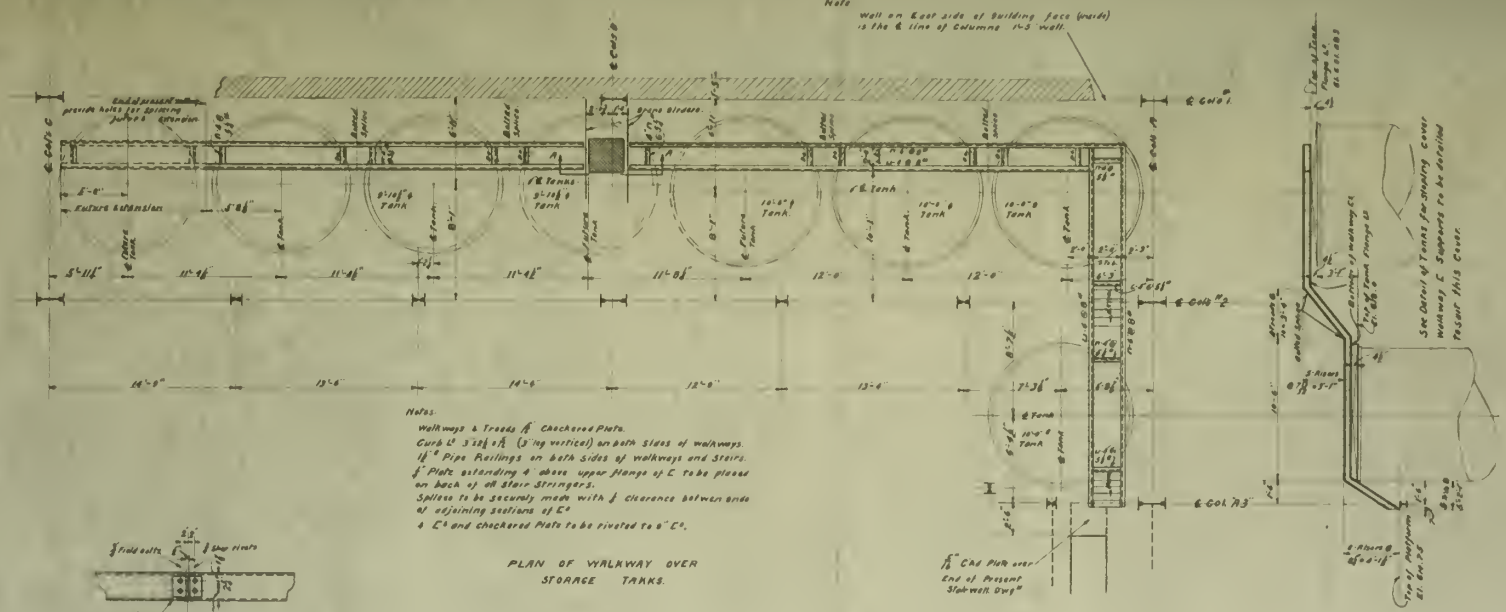
6 BRACKETS A
13" BRACKETS - B
ELEVATION SHOWING LOCATION OF BRACKETS
IN EAST WALL ABOVE WALKWAY
FROM BRIDGE TO STORAGE TANKS
PLAN OF WALKWAY
SECTION A-A
ELEVATION OF WALKWAY
Enlarged View of holes
in Floor Slab
For other holes and for drilling
of I Beam See Dwg.
Revisions
General
Pipe Brackets added
Pipe Brackets Revised
Pipe Brackets Revised
Added Opening
Holes in Floor slab shown
EVAPORATION HOUSE #2
BUILDING
PLATFORMS & WALKWAYS
HOOKER ELECTROCHEMICAL
NIAGARA FALLS, N Y
DRAWING NO.

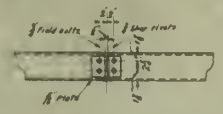
PLATE 23.



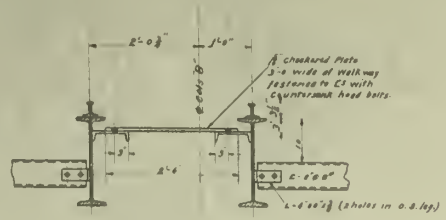
When future extension of walkway is made desk Platform to be removed to new position indicated by arrow.
END ELEVATION
END ELEVATION
Bolted connections.
Bolted connections
Bolted Connections for 6" L
Future steel shown dotted.
Section C-C.
Section B-B
Top of Tanks
Top of Mortar Platform
All Walkways 2 Stairways
Checkered Plate Floor & Treads
Curb L (both sides) 3 x 2½ x 5/16 - 3 leg vertical on walkways
1½" ø Pipe Railings - both sides
Plate on back of Stair stringers - Plate extending 4" above upper flange of L
EVAPORATION HOUSE
BUILDING
DETAIL OF WALKWAY OVER FILTERS
COOLERS, AND SETTLING TANKS.
HOOKER ELECTROCHEMICAL CO.
NIAGARA FALLS, N.Y.
DRAWING No 26023B

PLATE 24.





TYPICAL WALKWAY SPLICE.



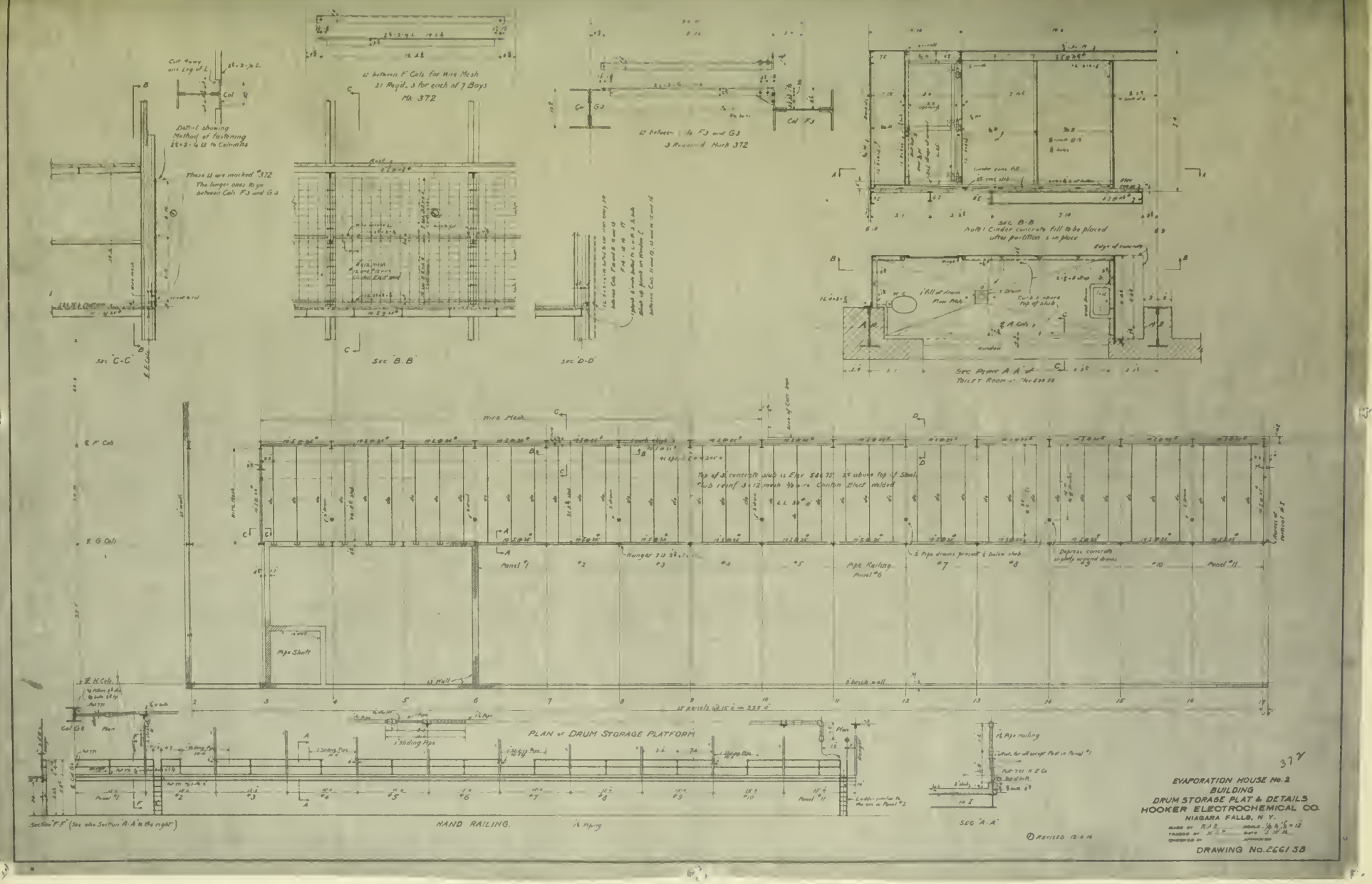
SECTION A-A.

EVAPORATION HOUSE No.2,
BUILDING.
WALKWAY OVER STORAGE TANKS.
HOOKER ELECTROCHEMICAL CO.
NIAGARA FALLS, N.Y.

Pipe Railing Dwg" 363

DRAWING No

PLATE 25



Sec "C-C"
Sec "B-B"
Sec "D-D"
Sec B-B
Note: Cinder concrete fill to be placed after partition is in place
Sec Plan A-A of Toilet Room
Wire Mesh
Pipe Shaft
Pipe Railing
Panel #1
Panel #6
Panel #11
PLAN of DRUM STORAGE PLATFORM
HAND RAILING
Section "F-F" (See also Section "A-A" to the right)
SEC "A-A"
EVAPORATION HOUSE No. 2
BUILDING
DRUM STORAGE PLAT & DETAILS
HOOKER ELECTROCHEMICAL CO.
NIAGARA FALLS, N. Y.
DRAWING No. 2661 SB

PLATE 26

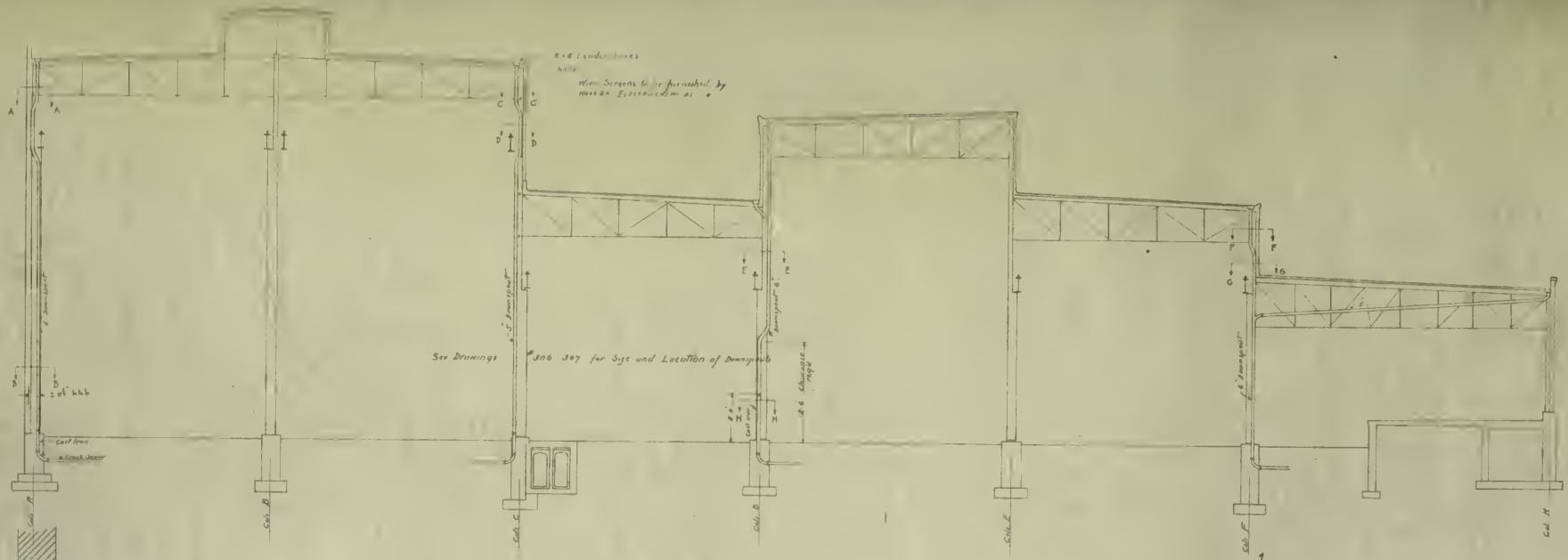
lines of 1½" pipe formed a handrailing for the sides of all walks and stairways; and throughout the building the idea of safety for the workmen was constantly borne in mind by the designing staff.

Drainage System for Building.

The drainage system for the building was also designed for future expansion. The area of the downspouts draining the roof was computed on the basis of 150 sq. ft. of roof area to one sq. in. of downspout area. The crickets on the roof were formed of cinder concrete, and were given a slope of ¼" per ft. to the leader boxes. All downspouts were of galvanized iron, and were held in position by strapping them to the columns. Floor washings in those parts of the building where there was but a small amount of the caustic soda were drained by concrete gutters to catch-basins, which were so constructed as to be easily entered for frequent cleaning.

To determine the number of toilets and fixtures required, the basis of fifteen men for every water-closet and wash-basin, and twenty-five men for each urinal, was used. Waste pipes were figured on the basis of twenty fixtures for a 4" pipe, thirty fixtures for a 5" pipe, etc., each water-closet and wash-basin counting as two fixtures, and a urinal as one. Lateral sewers of 6" and 8" vitrified tile carried all drainage to an outside line, which discharged into the city sewer. These sewers were given a minimum slope of 1%, and were of such capacity as to be ample for the completed building.

The water used in the process of manufacture of the caustic soda was obtained from the Hooker Electrochemical Company's pumping plant on the Niagara River nearby, but for drinking water, and for other sanitary purposes, the supply was obtained from the City mains.



SECTION A-A
Scale ¾" = 1'0

SECTION B B
Scale ¾" = 1'0

SECTION C C
Scale ¾" = 1'0

SECTION D D
Scale ¾" = 1'0

SECTION E E
Scale ¾" = 1'0

SECTION F F
Scale ¾" = 1'0

EVAPORATION HOUSE No 2
BUILDING
DETAILS of DOWNSPOUTS
HOOKER ELECTROCHEMICAL CO.
NIAGARA FALLS, N. Y.

DRAWING No. 7125 SB

PLATE 27.

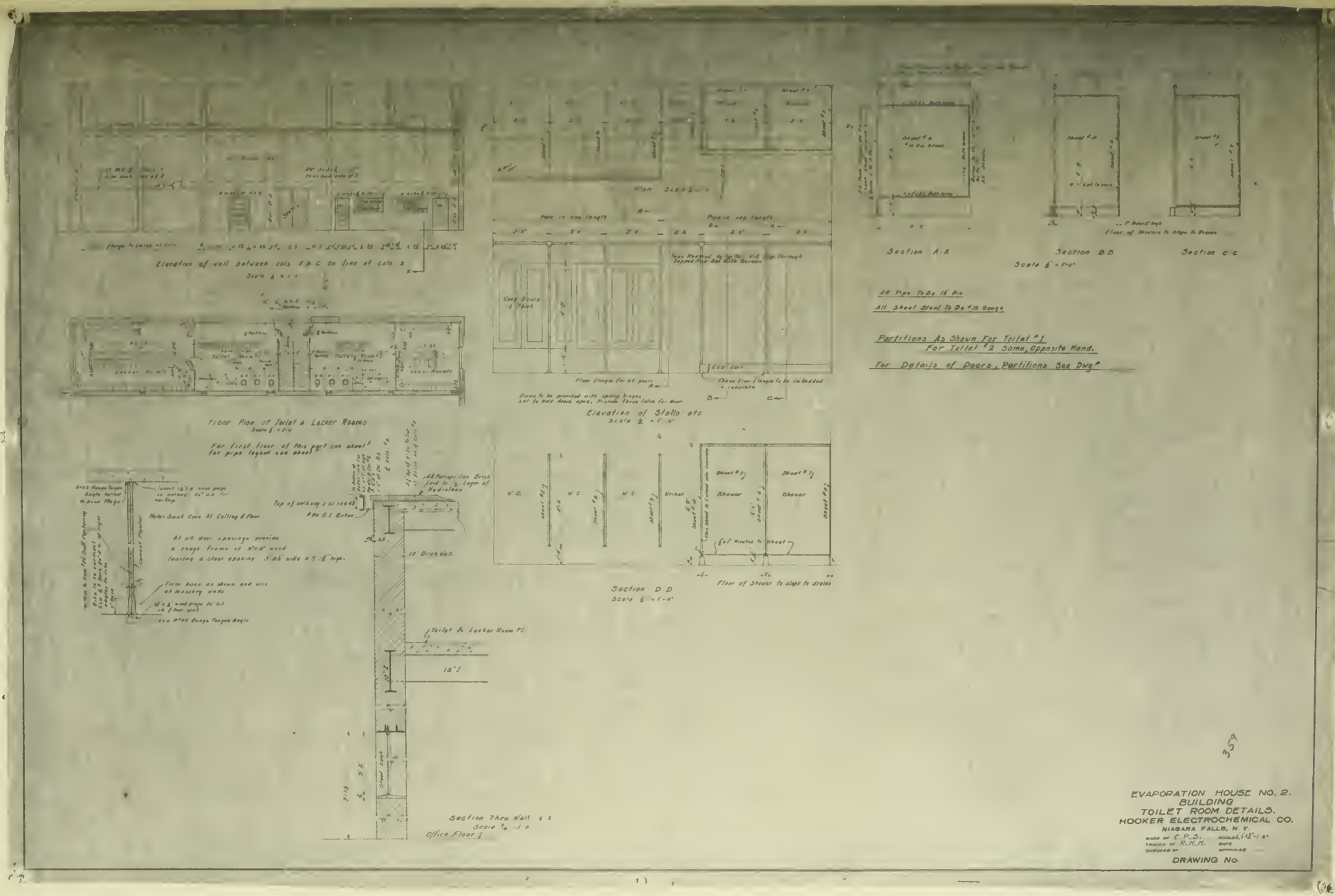

Elevation of wall between cols A & C on line of cols 2
Floor Plan of Toilet & Locker Rooms
Plan
Elevation of Stalls etc
Section A-A
Section B-B
Section C-C
All Pipe To Be 1½" Dia
All Sheet Steel To Be #16 Gauge
Partitions As Shown For Toilet #1
For Toilet #2 Same, Opposite Hand.
For Details of Doors, Partitions See Dwg #
Section D-D
Floor of Shower to slope to drains
Section Thru Wall
Office Floor
EVAPORATION HOUSE NO. 2.
BUILDING
TOILET ROOM DETAILS.
HOOKER ELECTROCHEMICAL CO.
NIAGARA FALLS, N. Y.
DRAWING No.

PLATE 28.

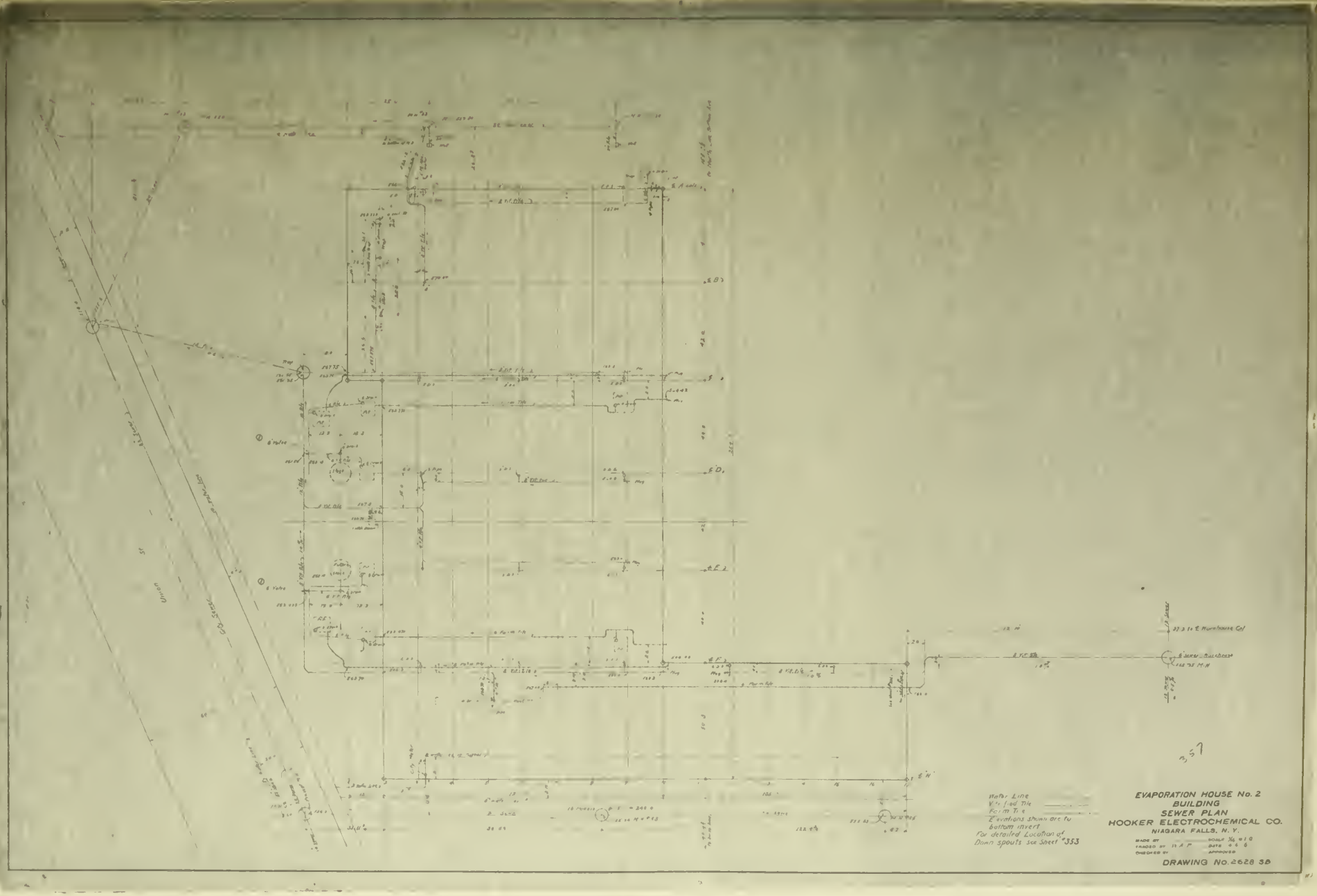

Water Line
Vit. Lined Tile
Conc. T. C.
Elevations shown are to bottom invert
For detailed Location of Down spouts see Sheet #353
EVAPORATION HOUSE No. 2
BUILDING
SEWER PLAN
HOOKER ELECTROCHEMICAL CO.
NIAGARA FALLS, N. Y.
DRAWING No. 2628 38

PLATE 29.

Interior Transportation.

The Hooker Electrochemical Company's plant is located next to the main line of the New York Central Railroad, and excellent shipping facilities were had. A spur track was built along the loading platform for shipping the finished product, and for bringing in the equipment from time to time. A five ton crane on cantilever runway girders, which extended out to the loading track, was provided in order to lift the heavy pieces of equipment from the cars, carry them back into the building, and deposit them on the trucks. These trucks were designed for a load of five tons, and ran on standard gage tracks to the various parts of the building. The 70# A.S.C.E. rails used were fastened by standard rail clips to ½" steel plates, which were bolted to a continuous reinforced concrete beam in the floor. A minimum radius of curvature of 25'-0", and a maximum grade of 0.5% was adopted, for under these conditions four men can push the loaded truck.

To bring the loaded trucks from the tracks at floor level to a height suitable for unloading the caustic drums, required a lift of six feet, up a grade of 15%. This was accomplished by means of a car haul. A 40 H. P. motor of 750 R.P.M. brought down to 2 R.P.M. on the driving sprocket, gave a car speed of 16 ft. per minute. The driving sprocket carried a link chain with fingers about six feet apart, which engaged a stop on the truck. Careful layouts of this feature were made in order to locate the point of engagement in the exact position which would give ease in operation. The track leading to the car haul was given a slight slope down, and the sprocket wheel at the low end of the car haul was so located that the chain fingers would engage the stop on the front of the truck before the front wheels could reach the up-grade.

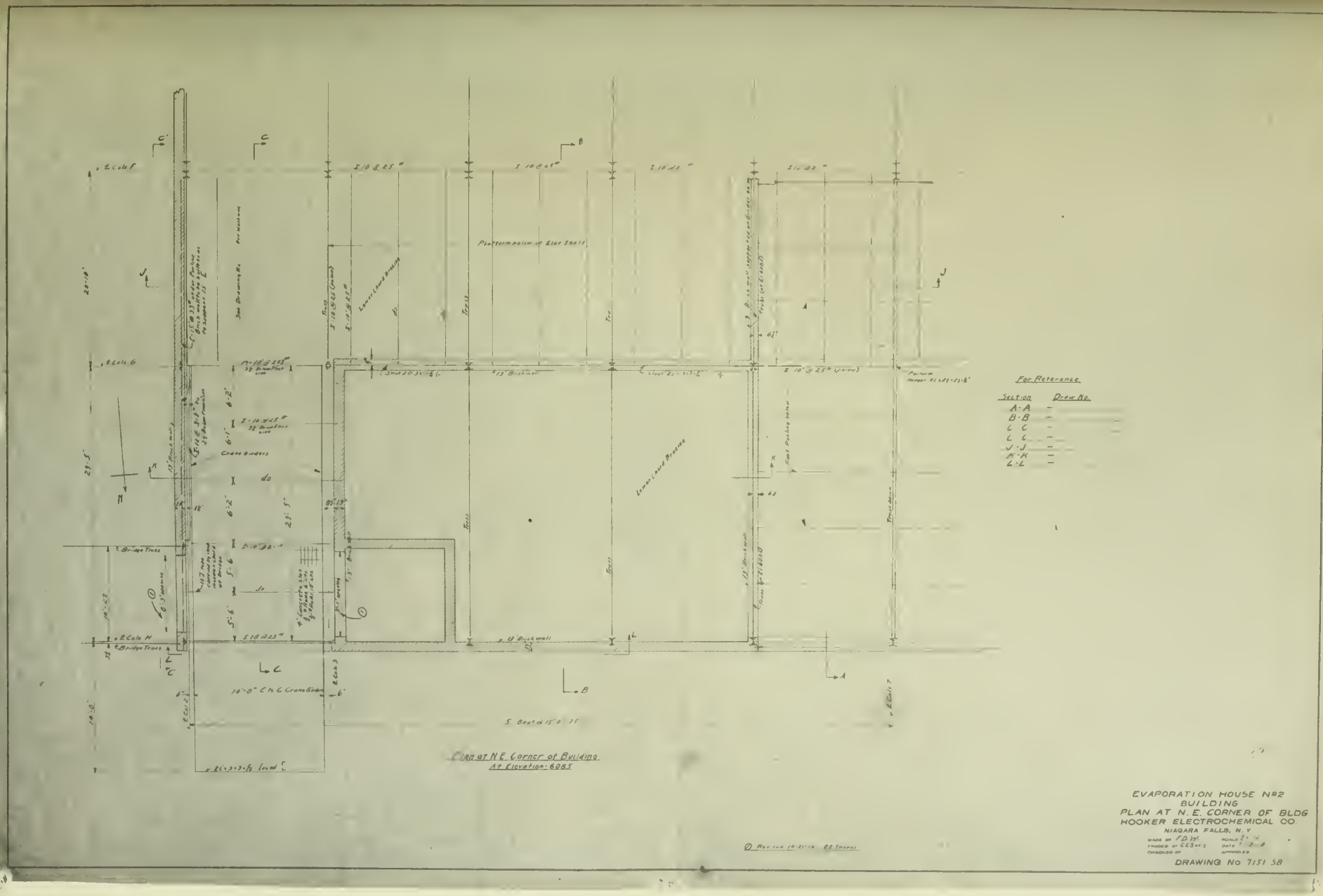
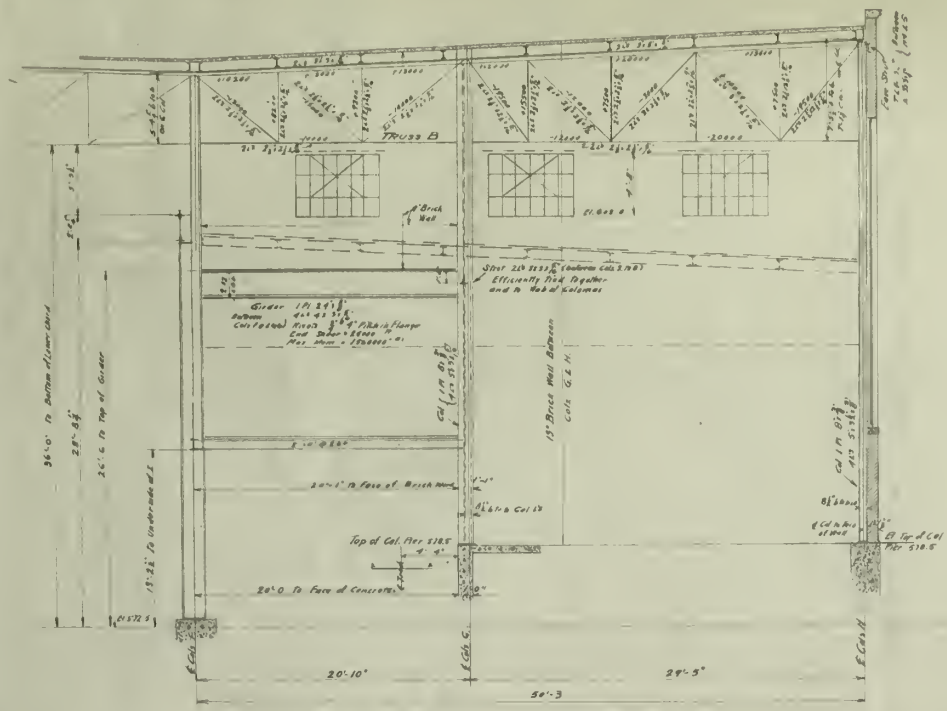
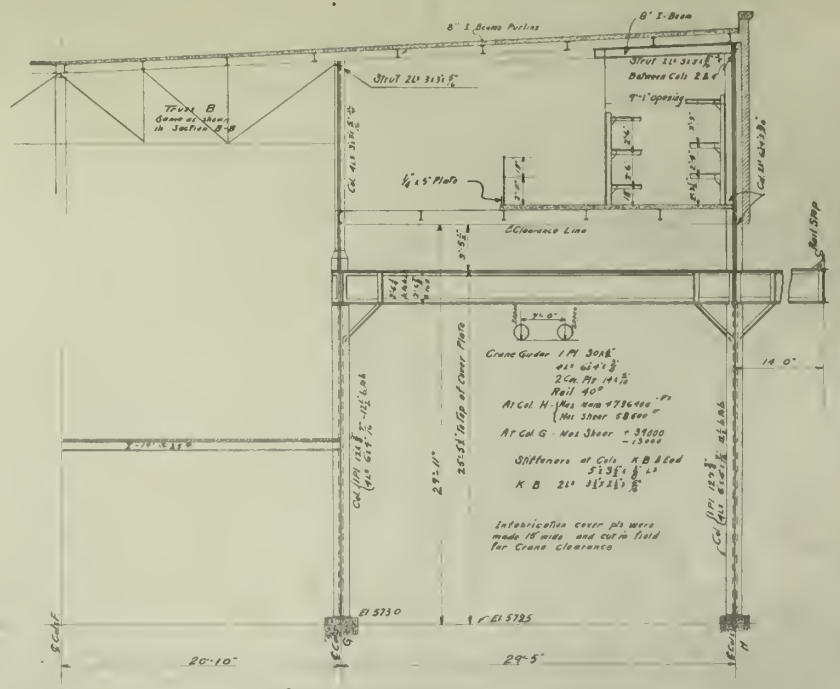

Platform below of Elev Seats
Lower Chord Bracing
Crane Girders
Bridge Truss
Truss
Plan at N.E. Corner of Building
At Elevation - 608.5
For Reference
Section Draw No.
A-A
B-B
C C
C C
J-J
K-K
L-L
EVAPORATION HOUSE No 2
BUILDING
PLAN AT N.E. CORNER OF BLDG
HOOKER ELECTROCHEMICAL CO.
NIAGARA FALLS, N.Y.
DRAWING No 7151 SB

PLATE 30.



GROSS SECTION B-B

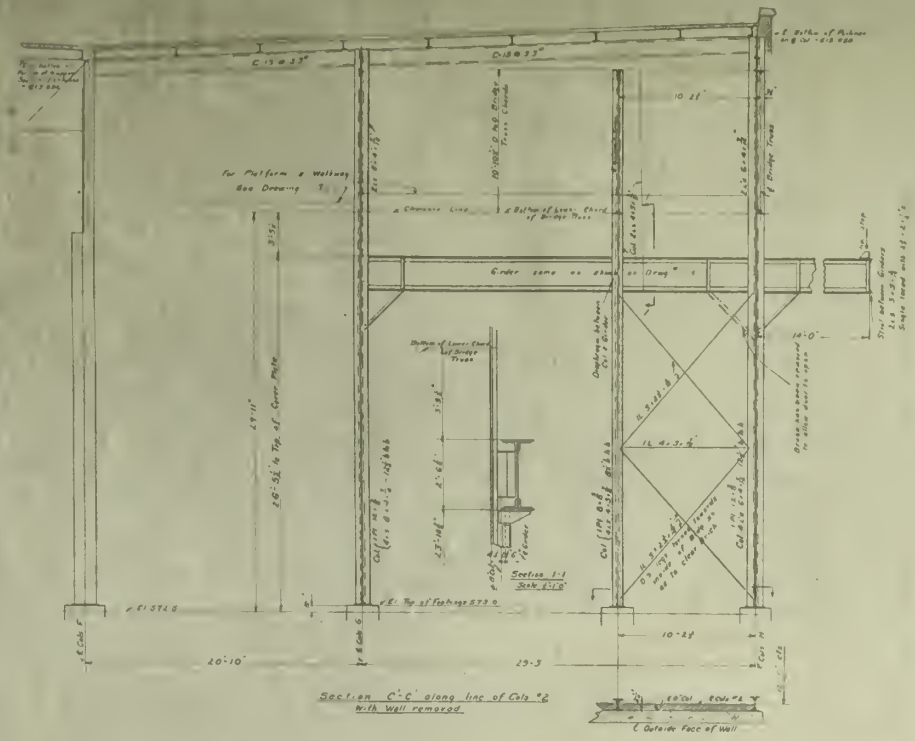


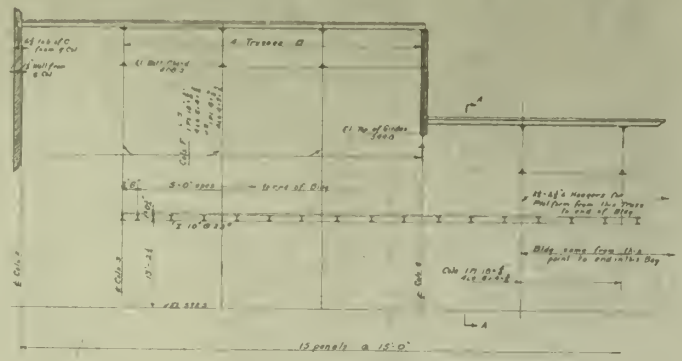
SECTION C-C

309

EVAPORATION HOUSE #2 BUILDING
SECTIONS B-B & C-C.
HOOKER ELECTROCHEMICAL CO.
NIAGARA FALLS, N.Y.
DRAWING NO 7170-38

PLATE 31





LONGITUDINAL SECTION ALONG LINE
OF SUSPENDED PLATFORM (looking South)
SECTION J'-J'
Scale 1"=1'-0"

EVAPORATION HOUSE NO. 2
BUILDING
SECTIONS C-C & J-J
HOOKER ELECTROCHEMICAL CO.
NIAGARA FALLS, N. Y.

DRAWING No. 26695B

PLATE 32

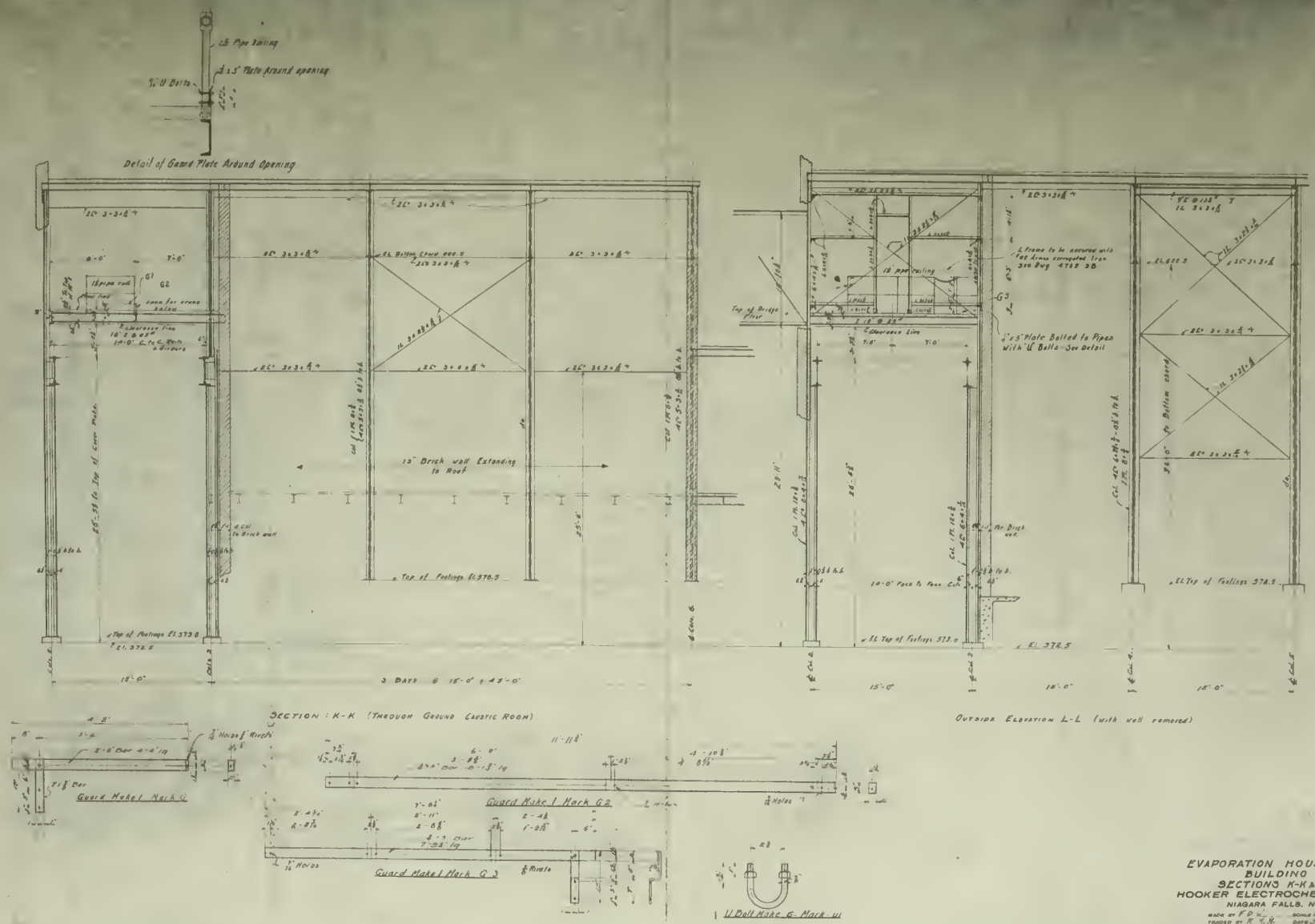

Detail of Guard Plate Around Opening
Guard Make I Mark G
Guard Make I Mark G 2
Guard Make I Mark G 3
U Bolt Make 6 Mark U
SECTION : K-K (THROUGH GROUND CAUSTIC ROOM)
OUTSIDE ELEVATION L-L (with wall removed)
EVAPORATION HOUSE No. 2
BUILDING
SECTIONS K-K & L-L
HOOKER ELECTROCHEMICAL CO
NIAGARA FALLS, N. Y.
DRAWING No. 7159-58

PLATE 33

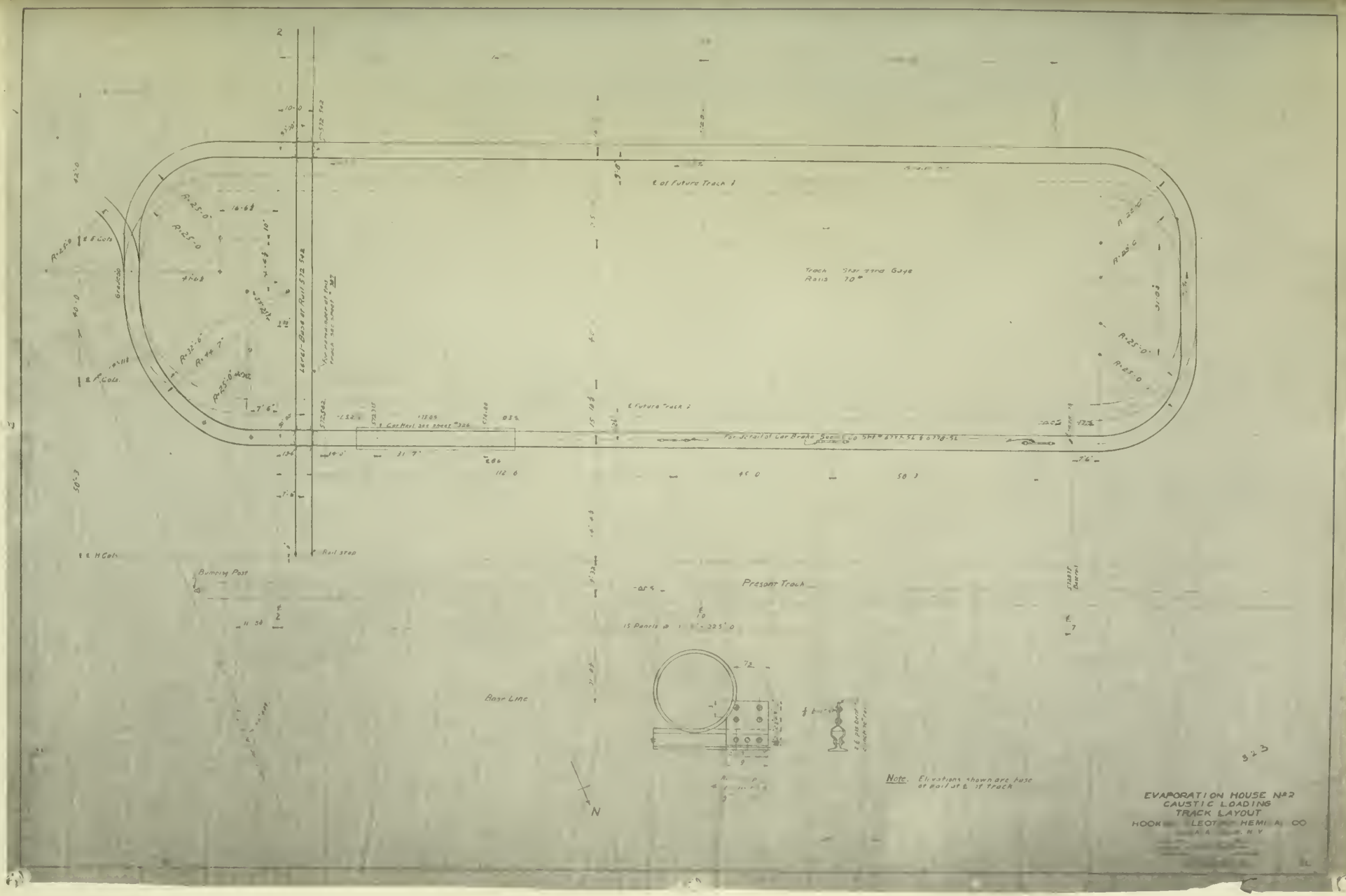

EVAPORATION HOUSE No 2
CAUSTIC LOADING
TRACK LAYOUT
Note. Elevations shown are base of rail at ℄ of track
Present Track
Base Line
Bumping Post
Rail stop
Track Standard Gage
Rails 70#
℄ of Future Track
Level-Base of Rail 572.542
N

PLATE 34

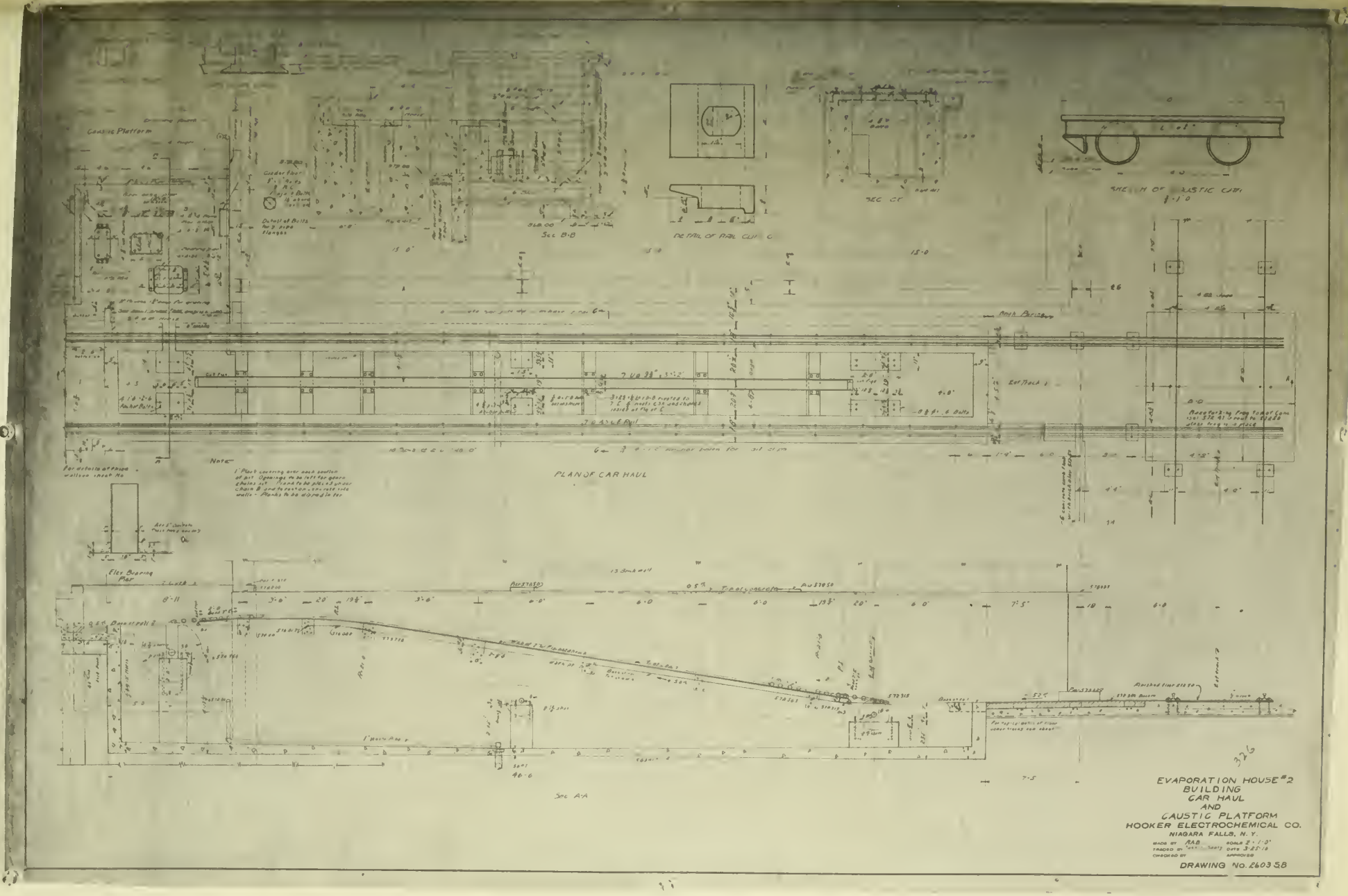

Caustic Platform
Sec B-B
DETAIL OF RAIL CLIP
SEC C-C
SKETCH OF CAUSTIC CAR
PLAN OF CAR HAUL
Note
Elev Bearing Pier
Sec A-A
EVAPORATION HOUSE #2
BUILDING
CAR HAUL
AND
CAUSTIC PLATFORM
HOOKER ELECTROCHEMICAL CO.
NIAGARA FALLS, N. Y.
DRAWING No. 2603 S8

PLATE 35

The tracks next to the loading platform were carried on reinforced concrete stringers, spanning 15'-0" to girders, which in turn were supported by retaining walls on each side. These beams were covered with a 4½" reinforced concrete slab, paved in the same manner as the main floor. The original intention was to lay the track on a fill, but later it was decided to make a reinforced concrete support on account of the settlement of the fill. The loading used in the design was for a string of trucks fully loaded, giving wheel concentrations spaced as shown in the diagram. The design of the stringers was as follows;

Instead of determining the theoretical moment for a series of continuous beams, each loaded, one beam was loaded with wheels placed in the position of maximum positive moment, and a reduction made for its continuity. The same amount of reinforcing steel was provided at the top over the supports as was computed at the point where the maximum positive moment occurred. The slab was not to be poured monolithically with the beams and girders, for reasons of operation, hence no "T" beam action was figured.

Wheel concentration = $\frac{10,000}{4}$ = 2500#

Impact 50% = 1250

Total under one wheel = 3750#

Uniform load = 110 x 3.6 + 300 =700#/ft.

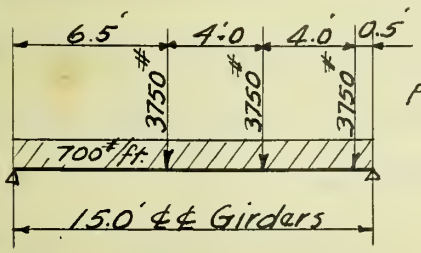
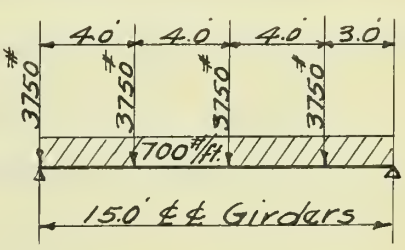


Fig. 4

Fig. 5.



Position for maximum moment. Position for maximum shear.

$R_1 = 700 \times 7.5 + \frac{3750\ (0.5 + 4.5 + 8.5)}{15} = 8620\#$ and $R_2 = 13,120\#$

$M = (8620 \times 6.97 - 350 \times 6.97^2 - 3750 \times 0.47)12 = 497{,}000\#"$

Reduced $M = 497{,}000 \times \frac{8}{12} = 331{,}000\#"$

$V_m = 700 \times 7.5 + 3750 \frac{(3 + 7 + 11 + 15)}{15} = 14{,}250\#$

Required A_c for shear $= \frac{14{,}250}{120} = 119$ sq. in.

Make b = 12", then jd = 10", and $d = \frac{10.0}{.875} = 11\frac{1}{2}"$

For moment, $d = \sqrt{\frac{331{,}000}{105 \times 12}} = 16.2"$, then jd = 16.2 x .875 = 14.2"

$A_s = \frac{331{,}000}{16.2 \times .875 \times 16000} = 1.46$ sq. in.

5- 3/4"ϕ rods were used, three bars being bent up on one side of the support, and two on the other side, giving the same steel top and bottom. The top bars were imbedded 3'-0" beyond the support, or about 48 diameters, and bottom rods were carried to the center line of the girder. All the rods had exactly the same bends, but were reversed, and placed as shown in the diagram.

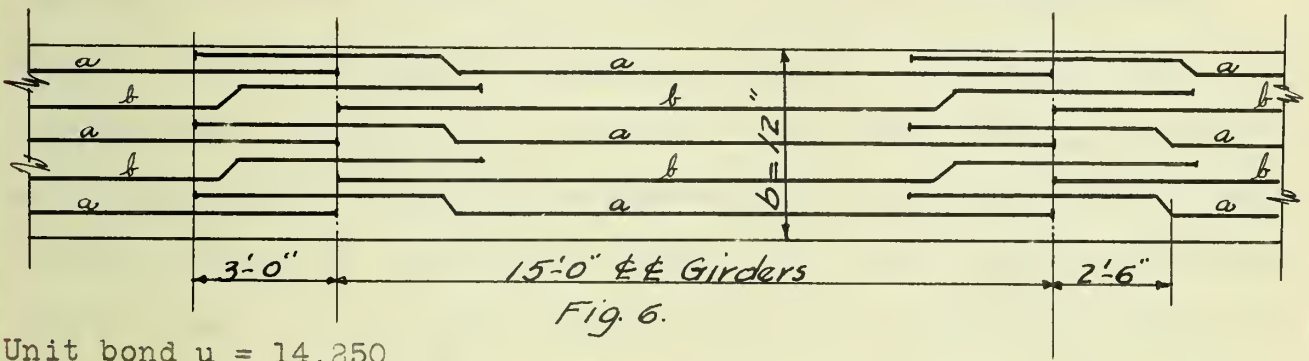


Fig. 6.

Unit bond $u = \frac{14{,}250}{14.2 \times 5 \times 2.35} = 85\#/$sq. in.

Unit shear $v = \frac{14{,}250}{14.2 \times 12} = 83.7\#/$sq. in.

V at 1st wheel = 14,250 - 4 x 700 = 11,450# and v = 67.1#/sq. in.

V beyond 1st wheel = 11,450 - 3750= 7,700# and v = 45#/sq. in.

The beam required reinforcing for shear about 5'-0" from support.

Diagonal tension at support $= \frac{14{,}250}{14.2} = 1000\#/$in. of length

" " " 1st wheel= $\frac{11{,}450}{14.2} = 800\#/$in. " "

Average diagonal tension = 900#/in. " "

Two-thirds of this is taken by the steel . The main reinforcing bars were bent up at 45° about 2'-6" from the support, and the

vertical stirrups were figured to take the diagonal tension. Using 3/8" ϕ rods of two prongs, the required spacing was

$$s = \frac{2 \times .11 \times 16000}{600} = 6"$$

This spacing was used for the first five feet, and 12" spacing was used for the middle five feet. The stirrups were placed below the longitudinal steel and the free ends were carried up into the slab, a hook being made on each end.

The loading platform, track support, and retaining walls were the least important in regard to the time of completion. This space was required as a roadway for assembling materials, and the men were need on other parts of the building, consequently this portion was not built until the more important parts were finished. Even the best made plans will go awry, particularly when working at top speed. The wall between the loading platform and the track was designed and built as a partition wall only, with but sufficient stability to resist the overturning of the earth-filled loading platform when the track was in place. This wall had been constructed and was left standing with its forms and bracing, and the fill in back was put in place from time to time. Through a misunderstanding, the bracing was removed so that the wall tipped several inches out of plumb. This was remedied by excavating along the inside of the wall, which easily returned to its former position under a slight pressure.

Design of Retaining Wall.

The reinforced concrete retaining wall along the south side of the track at the loading platform was built before the decision was made to provide a reinforced concrete support for the

track. It was designed as a cantilever wall of the "T" section, on Rankine's theory of earth pressure. The design is as follows:

Load on earth from truck = 10,000 x 1.5 = 15,000#

Line of thrust of earth acting at 45° strikes face of wall 3.75' below surface, or area of distribution = 7.0 ft. sq.

Then $w = \frac{15000}{7.0^2}$ = 300#/sq.ft.

Or at a depth of 2', (for 1 wheel next to wall),

$w = \frac{3750}{3.5^2}$ = 330#/sq. ft.

Assumed surcharge w = 300#/sq. ft.

Assumed earth fill w = 100#/cu. ft.

Fill in front was neglected on account of excavations, etc.

Earth thrust $P = .14 \times 100 (13^2-3^2)$ = 2240#

Line of action of P below mid pt. =

$\frac{(13-3)^2}{6(13+3)}$ = 1.05'

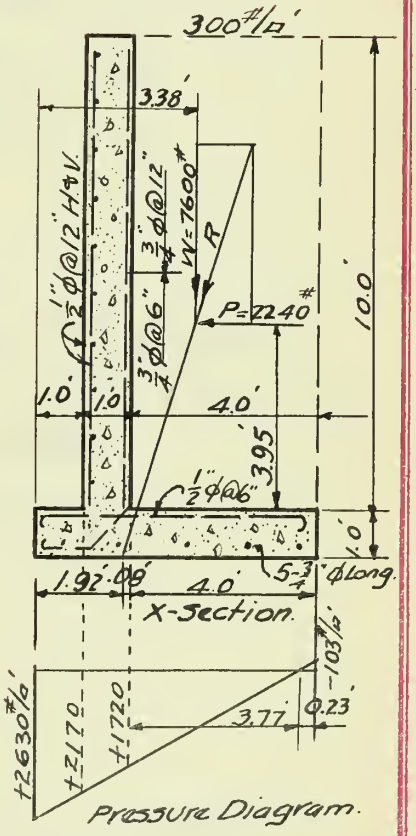
M at base of stem = 2240x3.95x12 = 106,000#"

$d = \sqrt{\frac{106,000}{105x12}}$ = 9.2" Make stem 12" thick.

A_s = .84 sq. in. $\frac{3}{4}$"ϕ at 12" extending to top of wall, and $\frac{3}{4}$"ϕ at 12" alternate extended to 5' from top, were used.

After two trials the final section of the wall stem and base was made as shown:-

Fig. 7.



Wt. of stem = 10 x 1 x 150 = 1500# M_a = 1500 x 1.5 = 2250#"

Wt. of base = = 900 " = = 2700

Wt. of E.& Surch. = 100 x 13 x 4 = 5200 " = 5200 x 4 = 20800

Total Wt. = 7600# Total M = 25750#"

c. g. = $\frac{25750}{7600}$ = 3.38' from toe

Factor of safety against overturning $= \frac{25750 \times 12}{108{,}000} = 2.9$

Factor of safety against sliding $= \frac{\tan 35^\circ \text{ or } .7}{\frac{2240}{7600}} = 2.4$

Resultant R strikes base at $\frac{2240}{7600} \times 4.95 = 1.46'$ from c. g.
or 1.92' from toe, or 0.08' outside kern.

Eccentricity from Center Line of base $= 3.0 - 1.92 = 1.08'$

Then $p = \frac{7600}{6} \times (1 \pm \frac{6 \times 1.08}{6})$ $= +$ 2630#/sq. ft. at toe.
$= -$ 103#/sq. ft. at heel.

Pt. of zero p $= 103 \times \frac{6.0}{(2630 + 103)} = .23'$ from heel.

p at face of wall $= \frac{4.77 \times 2630}{5.77} = 2170$#/sq. ft.

p at back of wall $= \frac{3.77 \times 2630}{5.77} = 1720$#/sq. ft.

Left Cantilever of Base---

Total P $= \frac{2630 + 2170}{2} \times 1.0 = 2400$#

M $= 2400 \times .5 \times 12 = 14700$#" Slab = 12"

Then d $= 12 - 2 = 10"$ and $A_s = \frac{14700}{10 \times .9 \times 16000} = 0.1$ sq.in/ft.

Inasmuch as the steel from stem was carried down and given a 3" hook, this portion was not designed further.

Right Cantilever of Base---

P $= \frac{1720}{2} \times 3.77 = 3240$#

Wt. of Earth Fill $= 5200$#

Then M $= (- 5200 \times 2.0 + 3240 \times 1.26) 12 = - 76000$#"

d $= \sqrt{\frac{76000}{105 \times 12}} = 7.8"$ Make Slab $= 12"$ Then d $= 10"$

$A_s = \frac{76000}{10 \times .9 \times 16000} = .53$ $\frac{1}{2}$" ϕ at 6" were used

p $= \frac{.5}{12 \times 10}$ or .417%

Then corrected j $= .902$ $f_s = \frac{76000}{10 \times .902 \times .5} = 16800$#/sq.in.

These bars were made straight, in the top of the slab for the

negative moment, and were given a 3" hook on each end. The wall bases were given a slight slope for drainage. Temperature reinforcing steel consisting of $\frac{1}{2}$"ϕ at 12" horizontally and vertically was placed in the stem of the wall. In the base 5-$\frac{3}{4}$"ϕ were placed longitudinally to assist in distributing the pressure along the wall.

In constructing the girders carrying the track stringers it was necessary to cut pockets in the wall for their support. Tar paper joints were made to avoid tying in the top of the wall, which would cause a reversal of stresses from those computed.

Furnaces, Flues and Stack.

The next important thing after the installation of the equipment for the evaporating, filtering, and cooling tanks was the construction of the furnaces, flues and stack. The walls of the furnaces were several feet thick, and lined throughout with firebrick. Directly over the fires were placed the caustic pots, huge iron cups weighing ten thousand pounds each, in which the caustic soda received its final treatment.

The hot gases from the furnaces were carried off to the stack by underground concrete flues. The temperature inside the flues was about 700° F., which was resisted by a 4" lining of firebrick on the sides, and an additional 4" of common brick for the arch at the top. Manholes and removable slabs were placed in the top throughout the entire length to give ease of accessibility for repairing the lining and for cleaning out. In addition clean-out pits were provided inside and outside the building. The side walls of the flues were designed as a vertical slab to sustain the earth

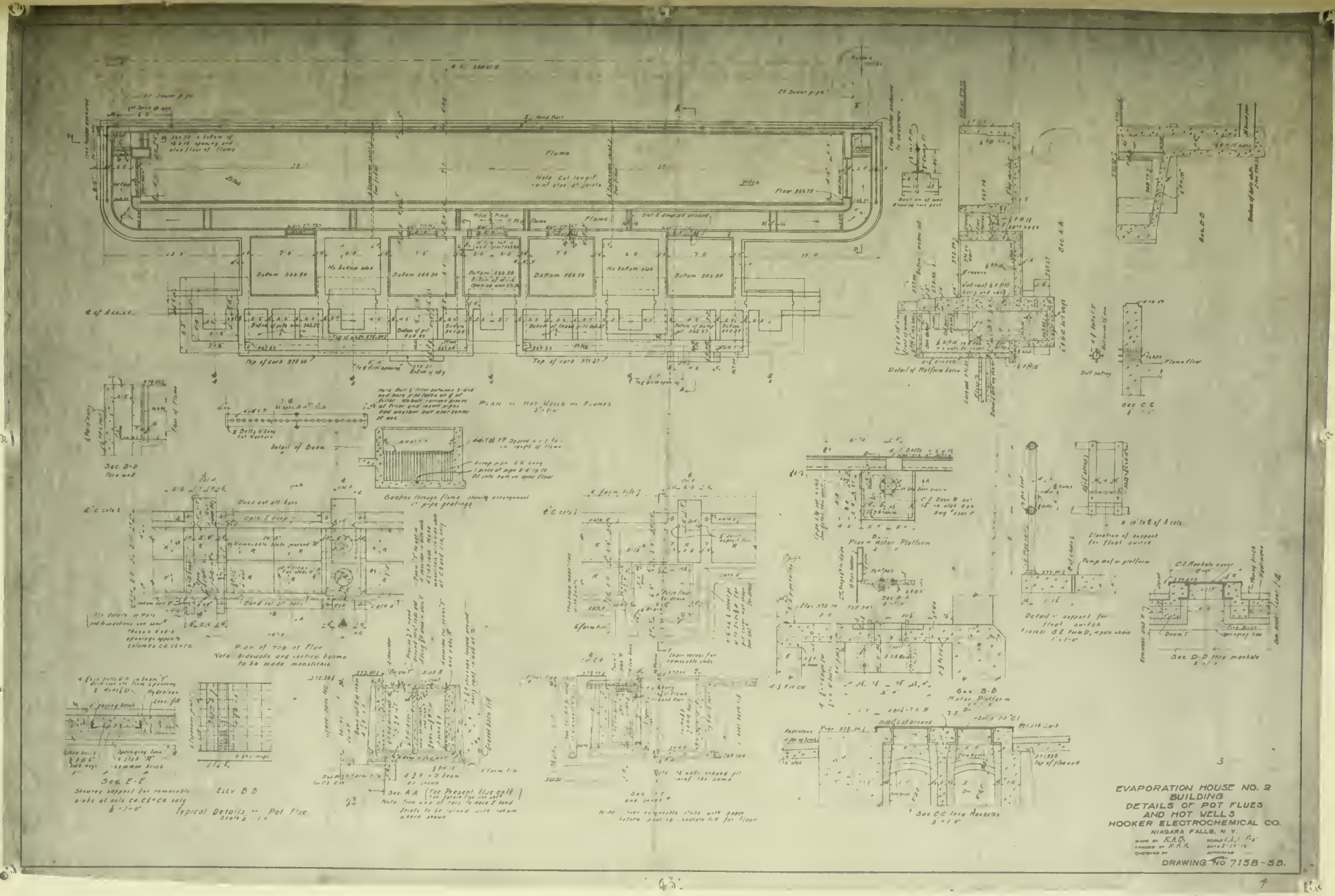
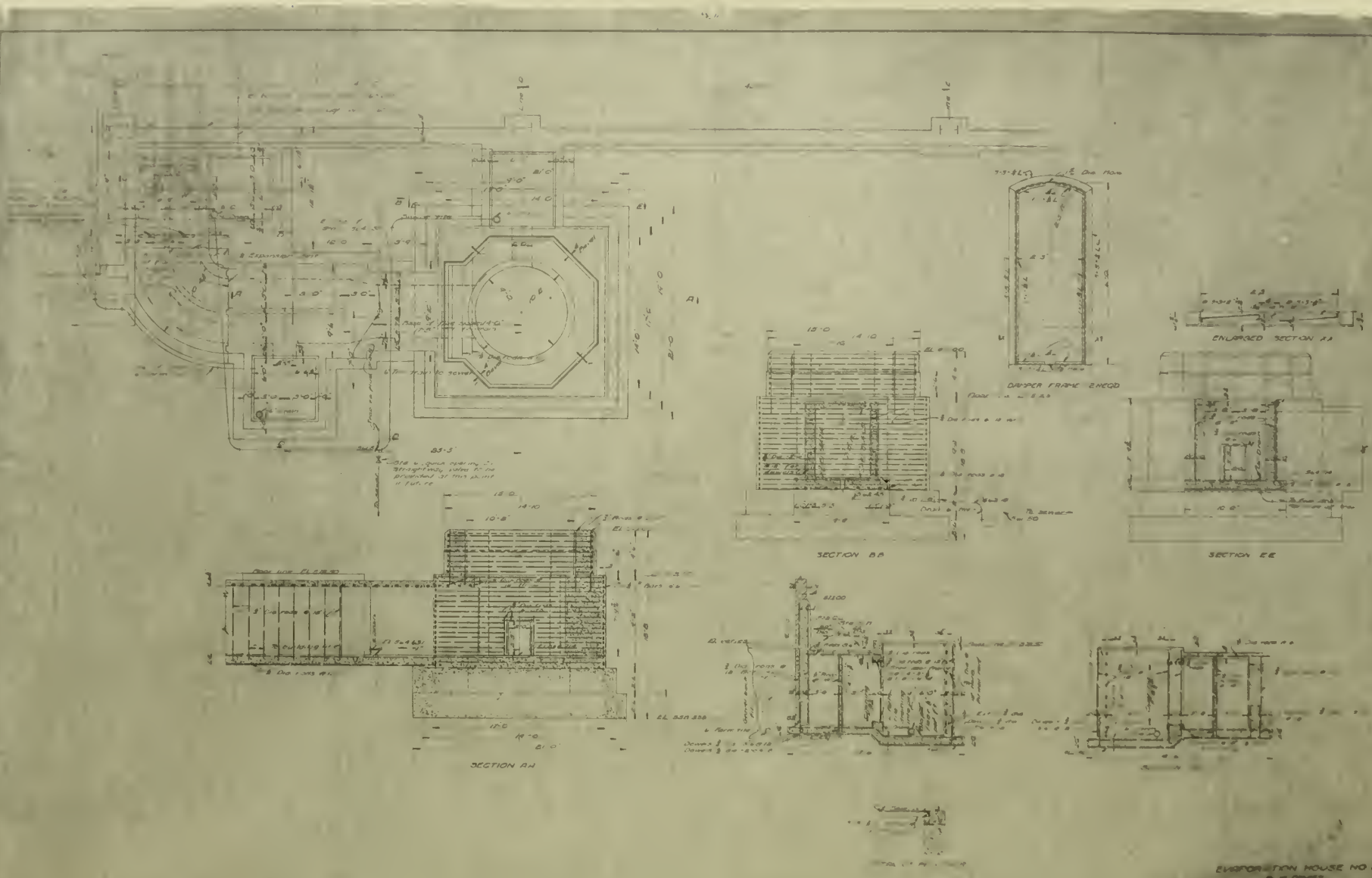

Flume
Bottom 366.50
No bottom slab
Top of curb 378.50
Top of curb 377.37
Plan of Hot Wells in Flumes
Detail of Beam
Sec. D-D
Geepes through flume showing arrangement of pipe gratings
Plan of Top of Flue
Note Brickwalls and vertical beams to be made monolithic
Sec. E-E
Elev. B-B
Typical Details of Pot Flue
Scale 3/4" = 1'-0"
Sec. A-A (For Present Flue only)
Sec. C-C
Note: Over removable slabs with paper before pouring concrete for floor
Plan of Motor Platform
Sec. B-B
Motor Platform
Sec. C-C thru Manhole
Detail of support for float switch
Elevation of support for float switches
Pump and platform
Sec. D-D thru manhole
EVAPORATION HOUSE NO. 2
BUILDING
DETAILS OF POT FLUES
AND HOT WELLS
HOOKER ELECTROCHEMICAL CO.
NIAGARA FALLS, N.Y.
DRAWING NO 7158-38.

PLATE 36


SECTION AA
SECTION BB
SECTION EE
ENLARGED SECTION AA
DAMPER FRAME ENCOD
EVAPORATION HOUSE NO 8
BUILDINGS
DETAILS OF FOUNDATION AND
FLUES - LEADING TO CHIMNEY
NOOR

pressure and a load on the floor of 1000#/sq. ft. because of the nearness of the furnaces. The side walls were designed to span for a distance of 12'-0" to a vertical beam. Expansion joints were provided every 15'-0" and a vertical beam built on each side of the joint. These vertical beams were supported by a 4" ledge in the bottom slab and by horizontal struts of concrete to the opposite wall. Expansion joints were ½" wide and 2" deep and were well caulked with oakum. The floors of the flues were given a slope toward the stack, and in addition a 6" farm tile was laid on each side to give thorough drainage. The grades and sizes of the flues were designed to give ample flue area for another battery of pots in the future building.

The design and construction of the stack was sub-let to a stack contractor. The foundation was built of heavily reinforced concrete carried down to a depth of 14'-0" below the surface. Provision was made in the exterior wall footing for a future flue, and all underground lines were kept clear of the site of the future stack. Each flue and stack was designed for two batteries having nine pots in each. The walls of the stack were of radial brick of varying thickness, the inside being lined with fire-brick. This stack was built to a height of 175'-0", with an internal diameter of 9'-0" at the base and 6'-0" at the top.

Caustic Recovery Pit.

The reinforced concrete sump or caustic pit was designed, as before mentioned, to recover the caustic from the floors. The operation of the pumps was to be automatic, which required a motor platform of concrete above the pits, and a roof of corrugated steel

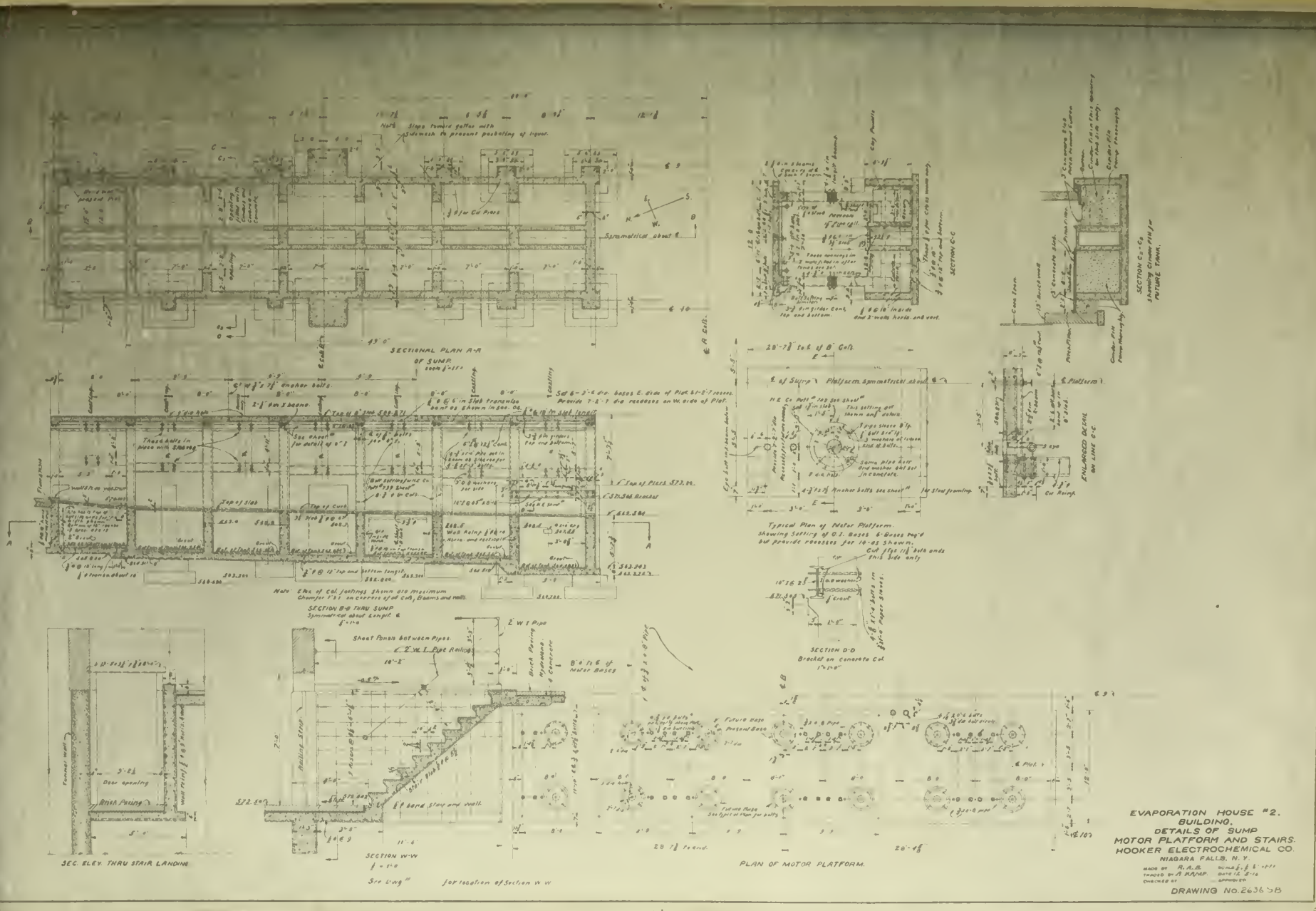

SECTIONAL PLAN A-A OF SUMP
SECTION B-B THRU SUMP
Typical Plan of Motor Platform
SECTION D-D
SEC. ELEV. THRU STAIR LANDING
SECTION W-W
PLAN OF MOTOR PLATFORM.
EVAPORATION HOUSE #2.
BUILDING.
DETAILS OF SUMP
MOTOR PLATFORM AND STAIRS.
HOOKER ELECTROCHEMICAL CO.
NIAGARA FALLS, N.Y.
DRAWING No. 263658

PLATE 38

above the platform. Concrete columns 12" square reinforced with 4-$\frac{3}{4}$"ϕ rods carried the motor platform, and also gave support to the shafting operating the pumps in the pits below. A trolley beam bolted to the underside of the motor platform beams, was to be used in renewing the equipment in the pits, and the hand-railing of $1\frac{1}{2}$" pipe was made removable for this purpose. This interesting structure is clearly illustrated on PLATE 38.

Tank Supports.

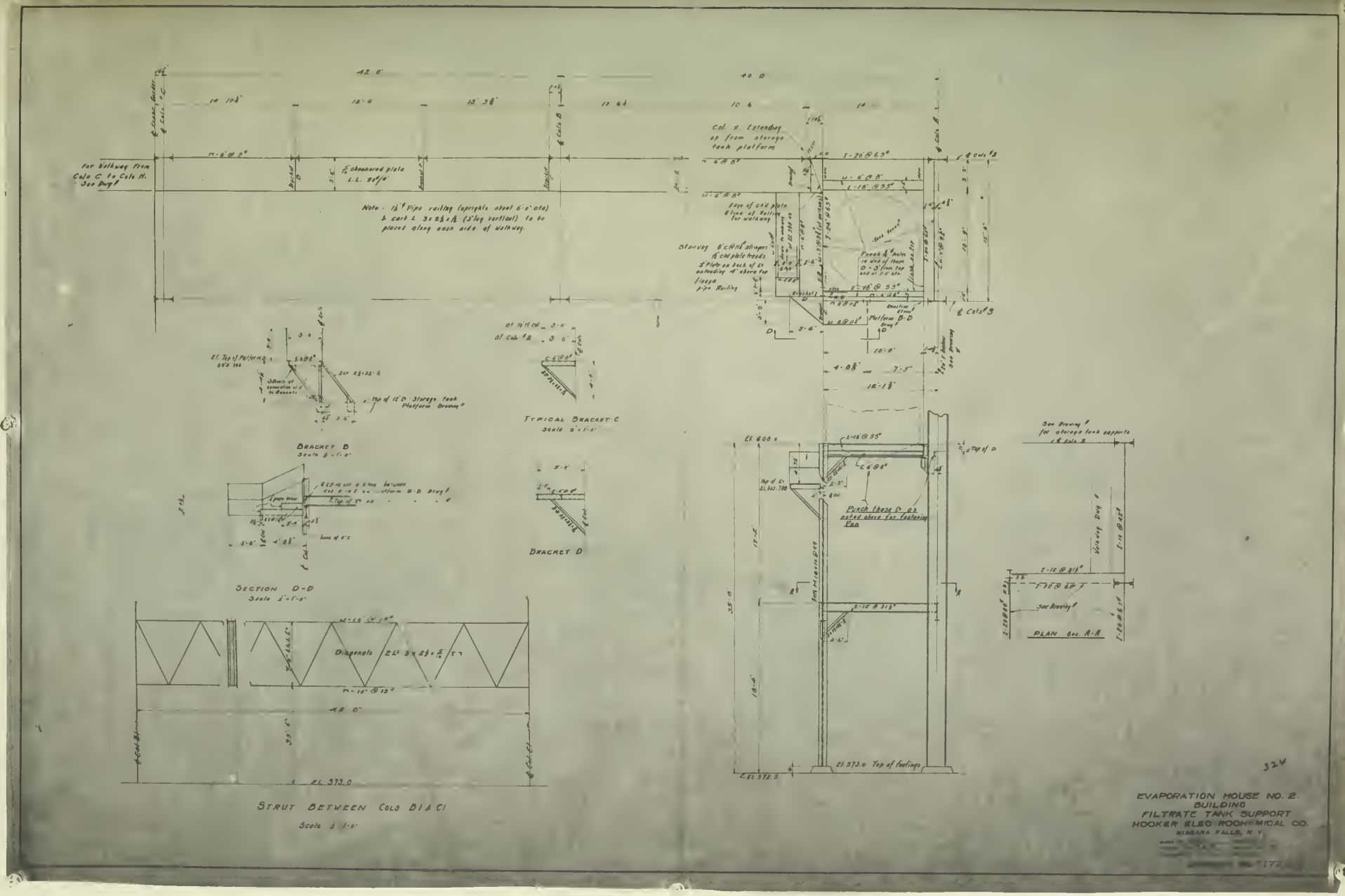
Numerous tanks were carried by steel framing which was designed with the same allowable stresses as for the main building steel work, as shown on PLATES 39-42.

The Pipe Bridge.

A steel bridge about 275 feet long supported on steel columns about 60 feet apart, was built to carry various pipe lines from the old plant to the new. The trusses, floors and columns, were designed for a uniform load of 100#/sq. ft., and a wind pressure of 30#/sq. ft. Pipes carrying the liquor of caustic soda, steam, compressed air, and the mono-chlor-benzol, were supported by brackets fastened to steel posts. The floor was constructed of 3" x 6" Yellow Pine spanning about 9'-0" to 2 -10" channel floor beams connected to the trusses at the panel points. Over the railroad tracks a 5" concrete slab was substituted. Details are as illustrated on PLATE 43.

The Pipe Tunnel.

At the connection of the bridge with the Evaporation House a vertical shaft to a reinforced concrete tunnel was built to bring the pipe lines beneath the building. The top slab of the



Bracket B
Section D-D
Typical Bracket C
Bracket D
Strut Between Cols B1 & C1
Plan Sec. A-A
Punch these D as noted above for fastening Pan
El. 573.0 Top of footings
EVAPORATION HOUSE NO. 2.
BUILDING
FILTRATE TANK SUPPORT
HOOKER ELEC ROCHEMICAL CO.
NIAGARA FALLS, N.Y.

PLATE 39

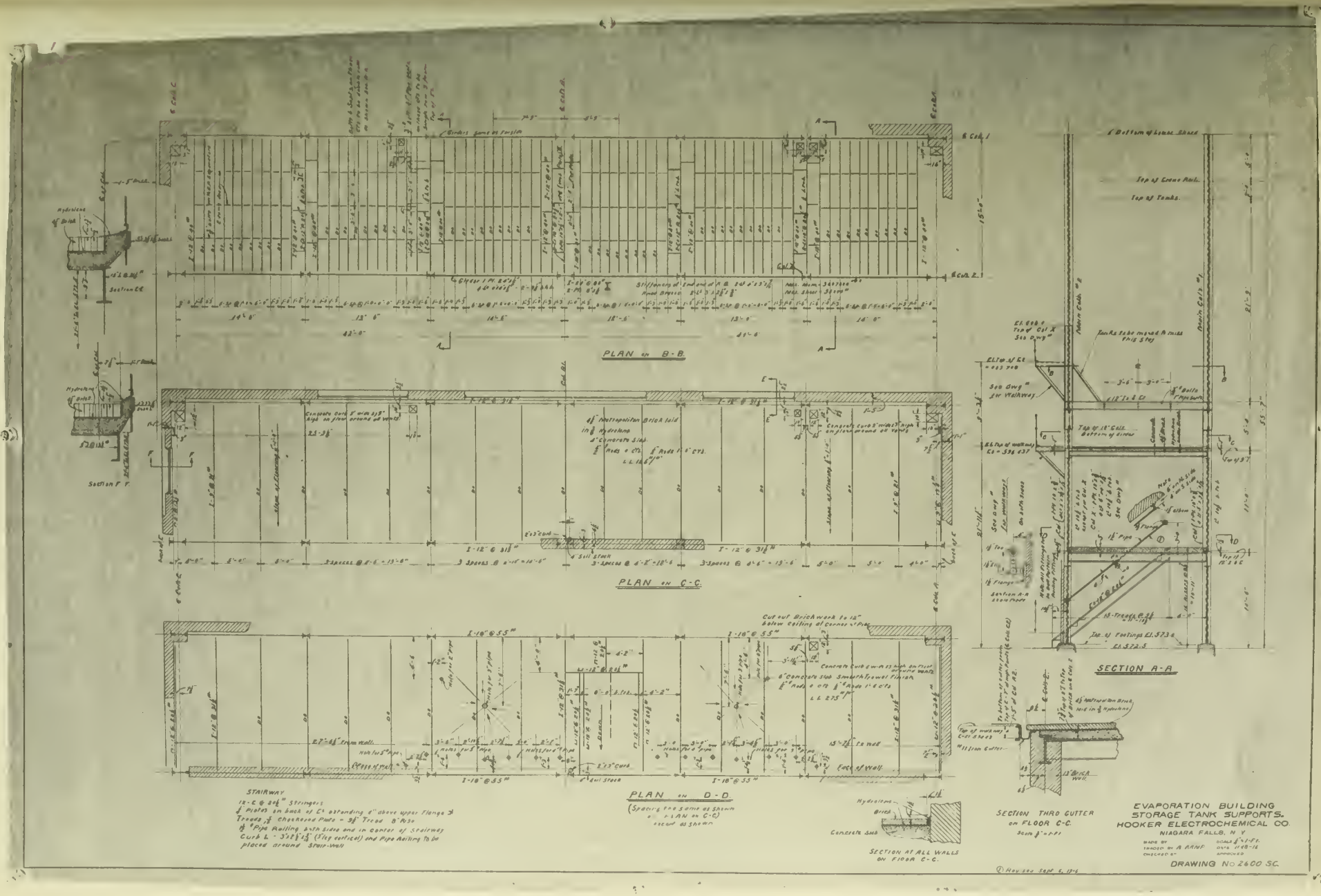

PLAN on B-B
PLAN on C-C
PLAN on D-D
SECTION A-A
SECTION THRU GUTTER on FLOOR C-C
SECTION AT ALL WALLS ON FLOOR C-C.
STAIRWAY
EVAPORATION BUILDING
STORAGE TANK SUPPORTS.
HOOKER ELECTROCHEMICAL CO
NIAGARA FALLS, N Y
DRAWING No 2600 SC.

PLATE 40

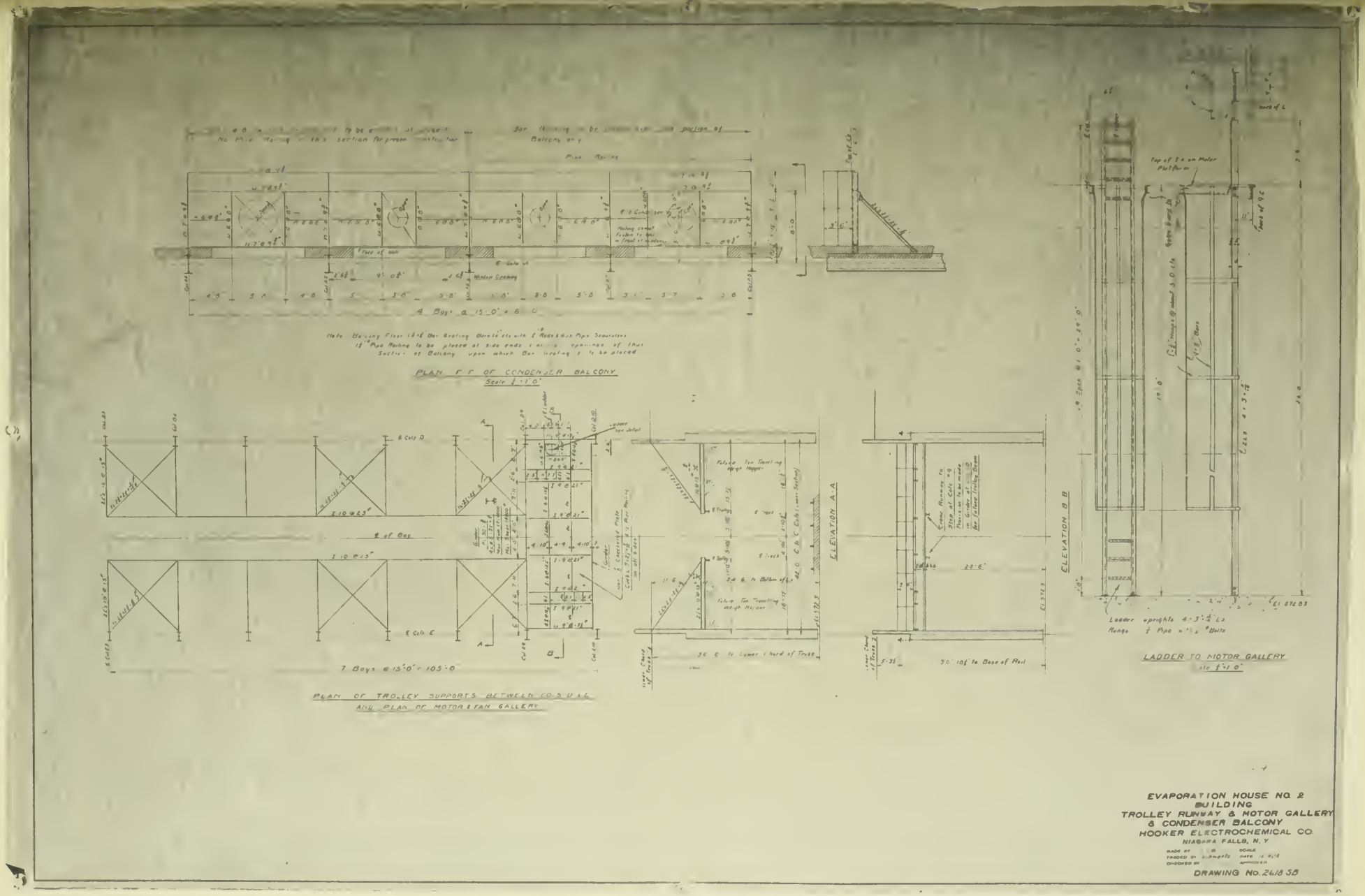
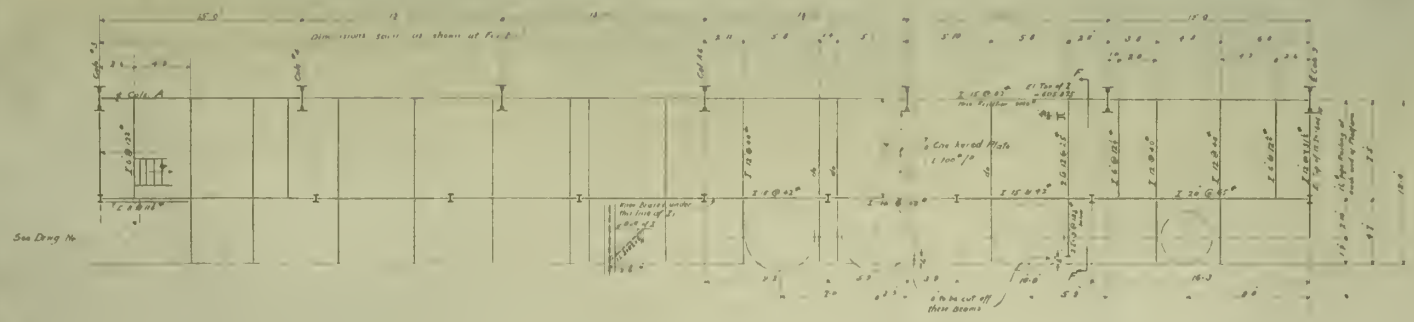
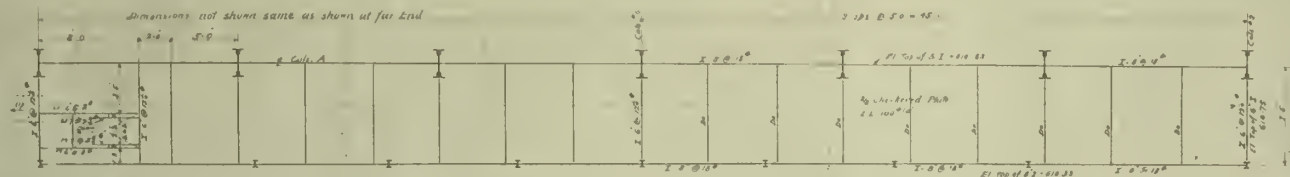

PLAN F F OF CONDENSER BALCONY
Scale 1/4" = 1'-0"
4 Bays @ 15'-0" = 6'-0"
PLAN OF TROLLEY SUPPORTS BETWEEN CO. S. D. & E.
AND PLAN OF MOTOR & FAN GALLERY
7 Bays @ 15'-0" = 105'-0"
ELEVATION A-A
ELEVATION B-B
LADDER TO MOTOR GALLERY
EVAPORATION HOUSE NO. 2
BUILDING
TROLLEY RUNWAY & MOTOR GALLERY
& CONDENSER BALCONY
HOOKER ELECTROCHEMICAL CO.
NIAGARA FALLS, N. Y.
DRAWING No. 2618 SB

PLATE 41

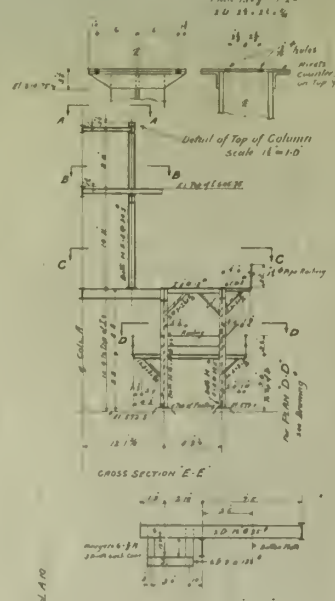


PLAN OF CANTILEVER PLATFORM
PLAN 'B B'



PLAN 'A-A' OF UPPER PLATFORM

PLAN 'C-C' OR LOWER PLATFORM



Detail of Top of Column
Scale 1" = 1'-0"

CROSS SECTION 'E-E'

SECTION 'F-F'

EVAPORATION HOUSE No. 2
BUILDING
EVAPORATOR TANK SUPPORTS
HOOKER ELECTROCHEMICAL CO.
NIAGARA FALLS, N.Y.

DRAWING No. 2L10 36

PLATE 42

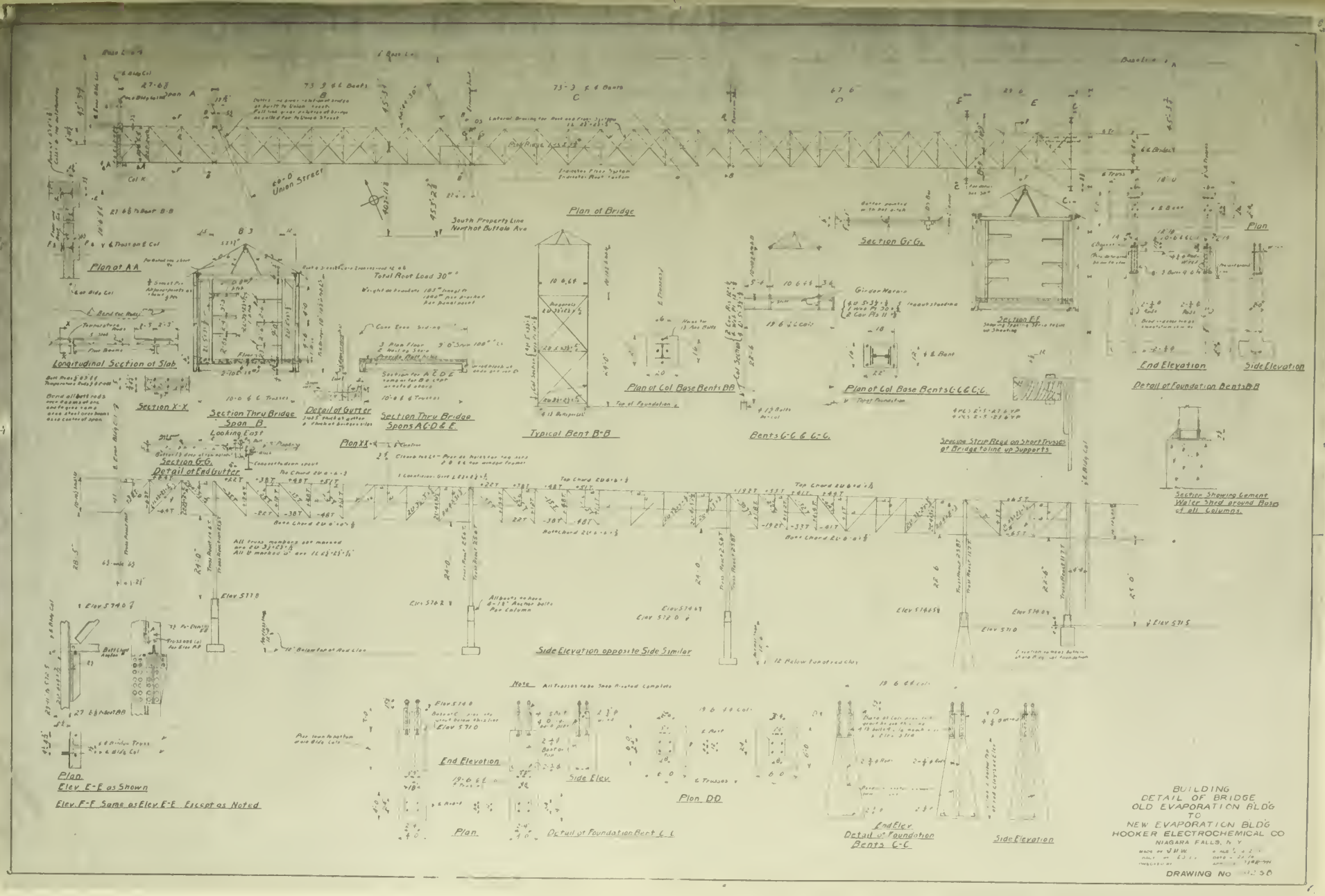

Plan of Bridge
Plan of A-A
Longitudinal Section of Slab
Section X-X
Section Thru Bridge Span B
Detail of Gutter
Section Thru Bridge Spans A-C-D & E
Typical Bent B-B
Plan of Col Base Bents B-B
Bents C-C & C-C
Plan of Col Base Bents C-C & C-C
Section G-G
Detail of End Gutter
Plan XX
Section G-G
Section F-F
Plan
End Elevation
Side Elevation
Detail of Foundation Bents B-B
Section Showing Cement Water Shed around Base of all Columns
Side Elevation opposite Side Similar
Plan
Elev. E-E as Shown
Elev. F-F Same as Elev. E-E Except as Noted
End Elevation
Side Elev.
Plan
Detail of Foundation Bent C-C
Plan D-D
End Elev.
Detail of Foundation Bents C-C
Side Elevation
BUILDING
DETAIL OF BRIDGE
OLD EVAPORATION BLDG
TO
NEW EVAPORATION BLDG
HOOKER ELECTROCHEMICAL CO
NIAGARA FALLS, N.Y.
DRAWING No

PLATE 43.

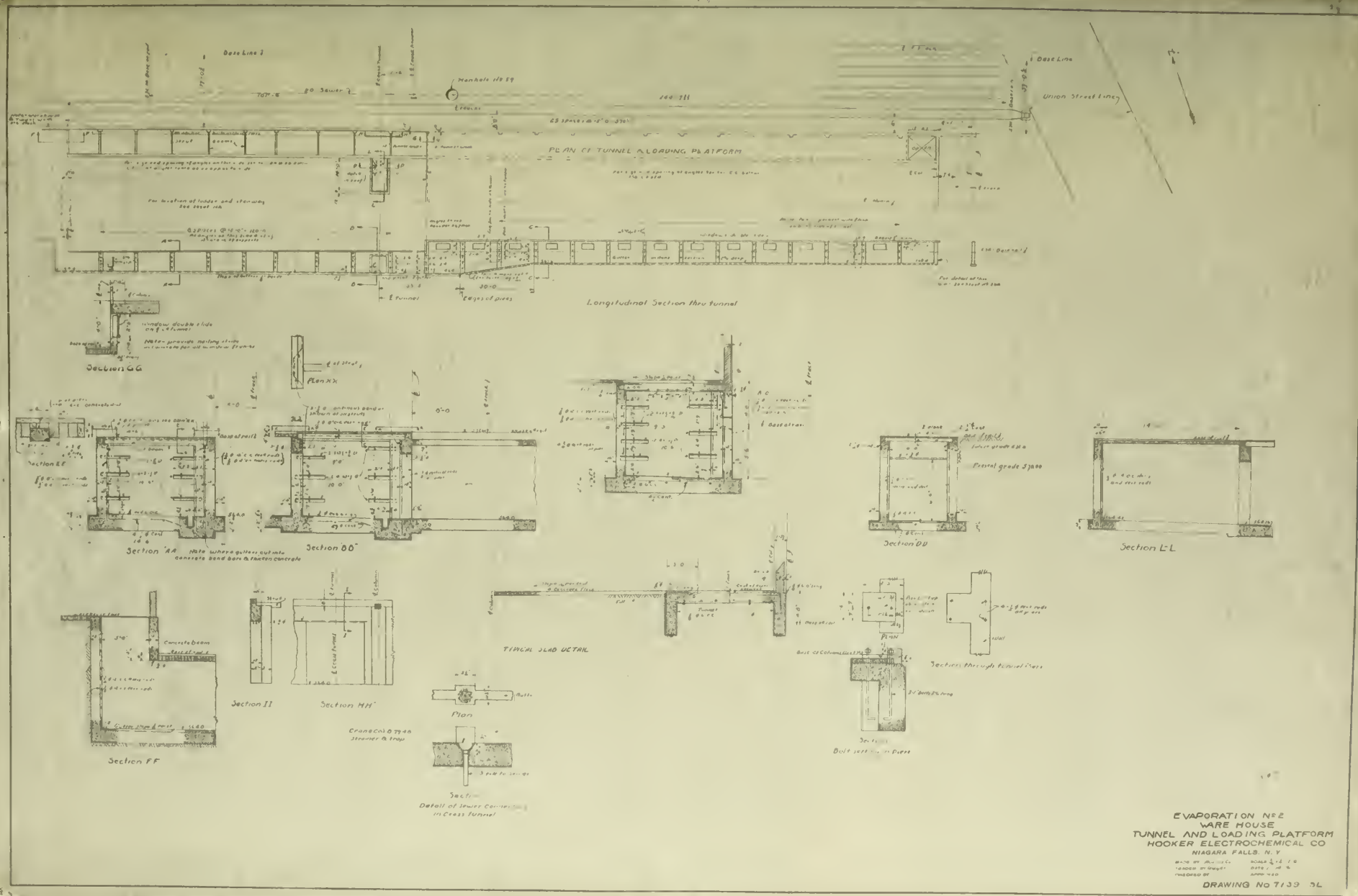

PLAN OF TUNNEL & LOADING PLATFORM
Longitudinal Section thru tunnel
Section GG
Section EE
Section AA
Section BB
Section DD
Section LL
Section FF
Section II
Section HH
TYPICAL SLAB DETAIL
Plan
Section through tunnel piers
EVAPORATION No 2
WARE HOUSE
TUNNEL AND LOADING PLATFORM
HOOKER ELECTROCHEMICAL CO
NIAGARA FALLS, N.Y.
DRAWING No 7139 SL

PLATE 44

tunnel was a portion of the loading platform, and was designed for a safe live load of 500#/sq. ft. The side walls were designed to withstand the pressure from the earth and a surcharge load from an E-40 engine on the tracks at the side of the building.

Because of the deadly effect of the escaping gases of chlorine and mono-chlor-benzol, windows 2'-6" x 5'-0" were placed in the side walls every 15'-0". Unfortunately even these proved insufficient, for three workmen entering the tunnel one day were overcome; two of them died, and the other suffered from the effect for several weeks. The company at once installed a system of forced ventilation to avoid any such future fatalities.

A number of other interesting and unique features were designed as a part of the equipment, such as the hot wells and flume, (PLATE 36); the drum storage suspended from the roof trusses, (PLATES 1 & 26); the steel grillage supports for the storage tanks, (PLATE 40); the catch basins, (PLATE 21); the car brakes under tracks; the various devices constructed for the safety of the workmen; and the different methods of protecting the steel work and the concrete from the action of the caustic soda.

III. CONCLUSION.

The unusual economic conditions and the heavy pressure, which was brought to bear to complete the building with the greatest possible speed and efficiency influenced the design and construction to no small degree. The building was erected in the midst of an industrial boom, when all materials were difficult to obtain, and labor was hard to secure and hold. The wages paid for labor varied, but the average was as follows:

Unskilled	$.27½
Structural steel workers	.65
Carpenters	.50
Brick-layers	.67½
Steam-fitters	.60

The designing staff for the contractors was established in the offices of the Owners, and a close co-operation was thus made possible between the designing and construction forces, and the engineers for the Owners. In fact the contractors were the building department for the Owners. They handled practically all purchasing of material and labor, charging everything up at cost, on which they received their commission on a "Cost-Plus" basis. The probable cost of the building had been determined in advance on a square foot basis, but a lump sum contract price was not possible, as the design and construction were carried on at the same time.

The contractors' purchasing agent kept a schedule of materials to be delivered as required, sublet contracts, and expedited the delivery of materials. All the structural steel was ob-

tained from the shops of the Buffalo Structural Steel Company, and deliveries were made in good time, according to schedule. The steel sash units were made of sizes which are commonly carried in stock, and were easily obtained. Good gravel was obtained locally, and deliveries were made as needed. Reinforcing steel was taken from the contractors' stock and was bent on the job.

The foundation plans were started February 14th, 1916, and the next day excavation work was begun. Operation began May 10th in the unfinished structure, and by July 1st the building was completed and turned over for operation, with the exception of a small portion held up by the Owners. This meant that in about four months time five thousand yards of earth were excavated, twenty-six hundred cubic yards of concrete were poured, five hundred and ten thousand bricks were laid, and one million five hundred and eighty thousand pounds of steel were fabricated, assembled, and riveted together. For a building of this character containing complicated steel framing for supporting equipment, and a great amount of difficult substructure work, the time of construction may be considered rapid.

The building could never have been completed in such a short time without the unflagging enthusiasm and tireless efforts of the entire force to reach the goal in the shortest time possible. The designing engineers worked early and late. Portions of the design, rather than the completed whole, were rushed to the field in order that the work might proceed steadily. The construction forces worked day and night, in three shifts, so that a stream of men aggregating twelve hundred converted what was once an open field into

a veritable bee-hive. The work was carried on logically according to a well defined plan. Concrete was poured into excavations as soon as made, and the work was planned so that the brick, steel and other work was put in place without interruption or delay. To accomplish this it was necessary to promote co-operation and harmony among the various trades.

In constructing a building with such rapidity, necessarily, extra capital was expended. Laborers were given higher wages than they would otherwise have been paid, to attract them to the work, and to induce them to work longer hours. Materials were somewhat more expensive, as quick deliveries were imperative. But "speed and efficiency" was the slogan, rather than economy of construction, and the Hooker Electrochemical Company considered the extra capital well placed. For the special efforts of the engineers had not only secured for them a first-class building, but also enabled them to bring returns on their investment quickly, by obtaining, at a favorable time, a good hold on the markets for their product, caustic soda.

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